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SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

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Experiments from the Flotation Laboratory

C. Y. CLAYTON

ROLLA, MISSOURI

6468
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Press of
Missouri Printing & Publishing Co.
Mexico, Missouri

Entered as Second-Class Matter November 29, 1911, at the Post-Office at Rolla, Missouri, under the Act of July 18, 1894. Issued Quarterly

Volume Three — Number One

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

BULLETIN

AUGUST, 1916

TECHNICAL SERIES

Experiments from the Flotation Laboratory

C. Y. CLAYTON

ROLLA, MISSOURI

6458
31-7

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Mexico, Missouri

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THE MINING EXPERIMENT STATION

Officers of the Station

Albert Ross Hill, Ph. D., LL. D.....*President of the University*
Austin Lee McRae, S. D...............*Director*
Guy Henry Cox, Ph. D., E. M.........*Geology and Mineralogy*
Carroll Ralph Forbes, E. M. ......*Mining*
Victor Hugo Gottschalk, M. S.....*Chemistry*
Horace Tharp Mann, E. M.,..........*Metallurgy and Ore Dressing*
Martin Harmon Thornberry, B. S...*Research Assistant*
Robert John Anderson, B. S. ....*Research Assistant*
Carl Godfried Stifel, B. S.........*Research Assistant*
William Kennedy Hunter, A. B.....*Flotation Expert*

The Mining Experiment Station was established June 1, 1909.

It is the object of the Station to conduct such original researches or to verify such experiment as relate to the properties and uses of mineral products; to investigate the engineering problems connected with the mineral industry, the economic methods of mining and the preparation of mineral products, the methods of preventing waste of the mineral resources and the methods of preventing accidents in mines, mills, and smelters; to assist in improving the conditions surrounding the labor in mines, mills, and smelters; and such other researches or experiments as bear directly upon the applications of mining and metallurgical engineering to the mineral industry of the State of Missouri.

Any resident of the State may on request obtain bulletins as issued, or if particularly interested, may be placed on the regular mailing list. Correspondence regarding these bulletins or the work of the Station may be addressed to the Director, Mining Experiment Station, Rolla, Missouri.

The work in concentrating ores by oil flotation was done in co-operation with the *State Geological Survey* and the *U. S. Bureau of Mines.*

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

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Experiments from the Flotation Laboratory

CHAS. Y. CLAYTON

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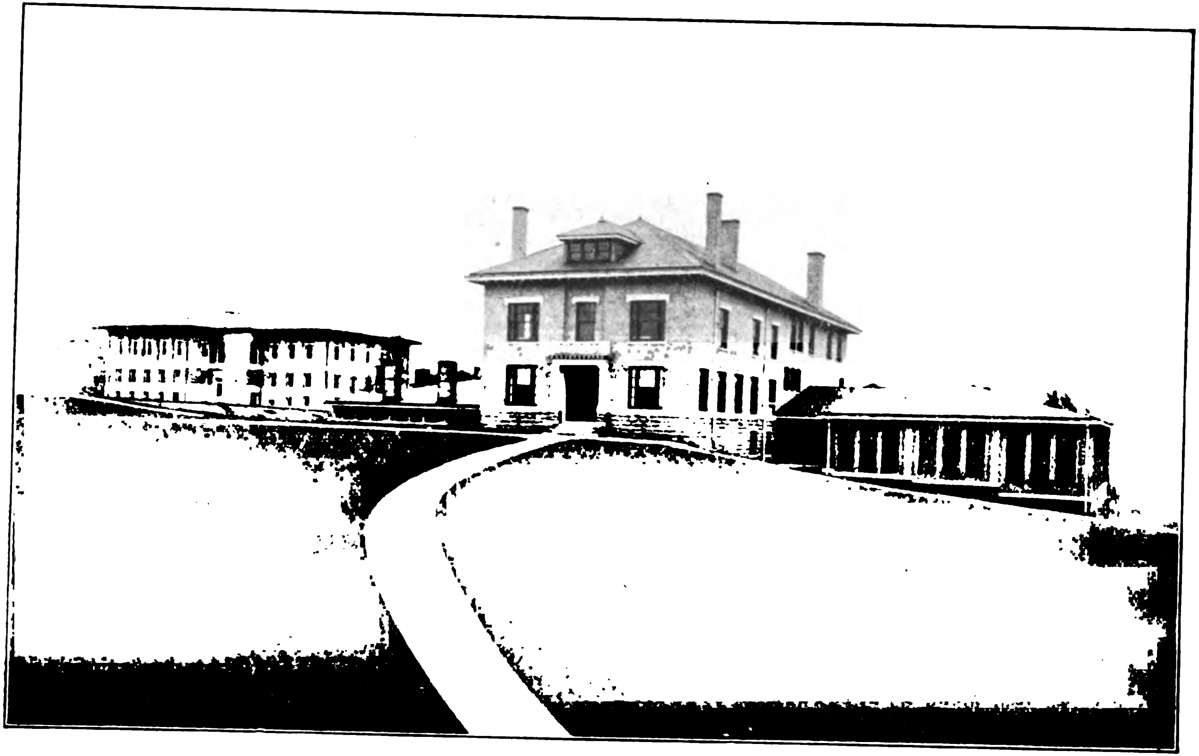

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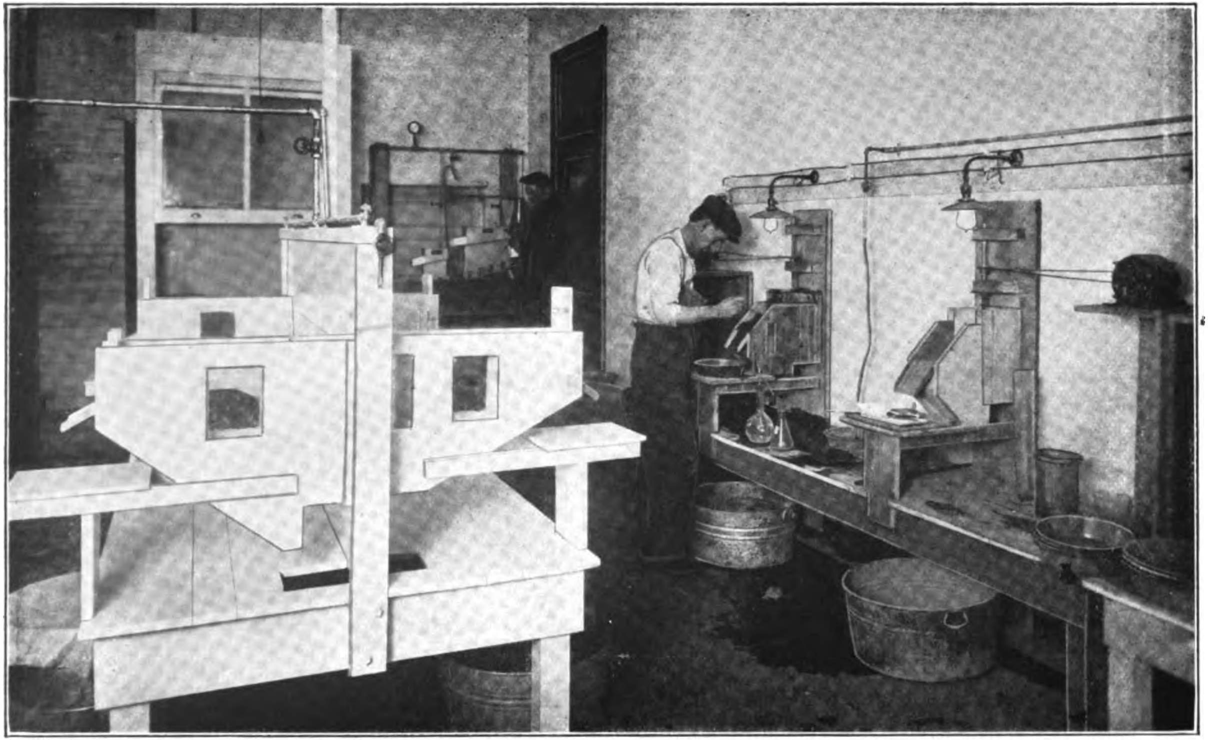

FLOTATION LABORATORY.

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FOREWORD

During the past year the Metallurgy department and the Experiment Station have carried on various laboratory experiments on concentrating ores by oil flotation. Some of the experiments gave negative results, some have been given in papers published in the technical press, others have been collected and arranged for publication in this bulletin. It is recognized that much of the data given is incomplete and requires further investigation, but it is published in the hope that it may aid other experimenters, save duplication of work and suggest other lines of research. Further work will be carried on during the coming year.

Acknowledgment is made to D. A. Lyon, Metallurgist, and O. C. Ralston, Assistant Metallurgist, of the United States Bureau of Mines, for advice and helpful suggestions, and to the oil companies for courtesies extended.

BULLETIN
OF THE
School of Mines and Metallurgy
UNIVERSITY OF MISSOURI

Vol. III. AUGUST, 1916 No. I

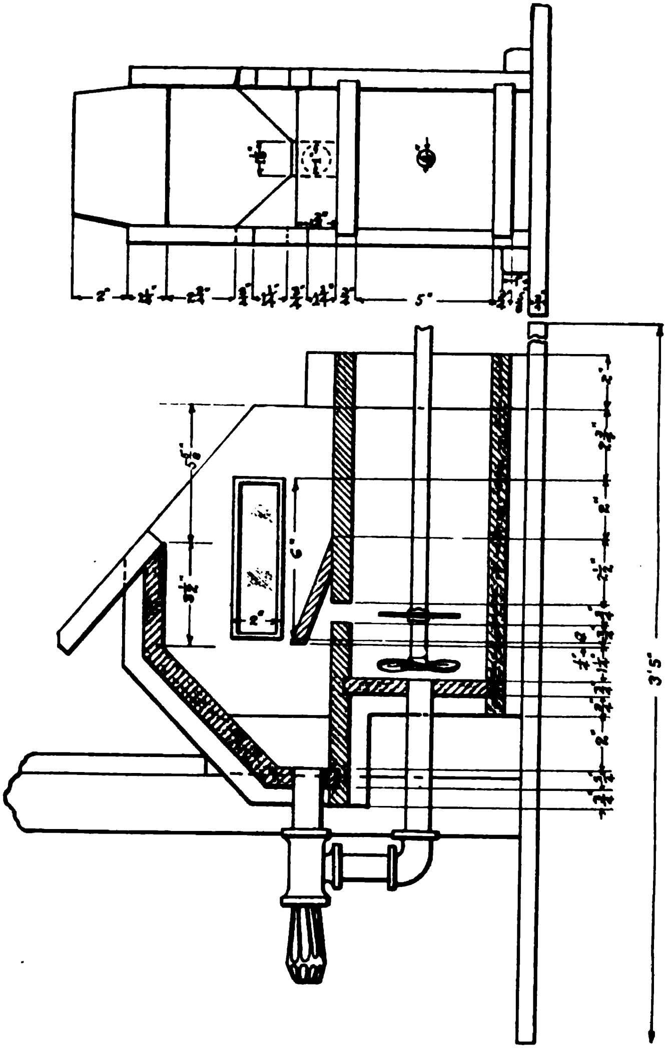
LABORATORY FLOTATION MACHINES

The first flotation work done in the Missouri School of Mines laboratory was with a standard slide machine described in Hoover's book on flotation. This machine gave good results but difficulty was experienced with grit getting in the lower bearing of the impellor shaft causing it to wear excessively and to leak.

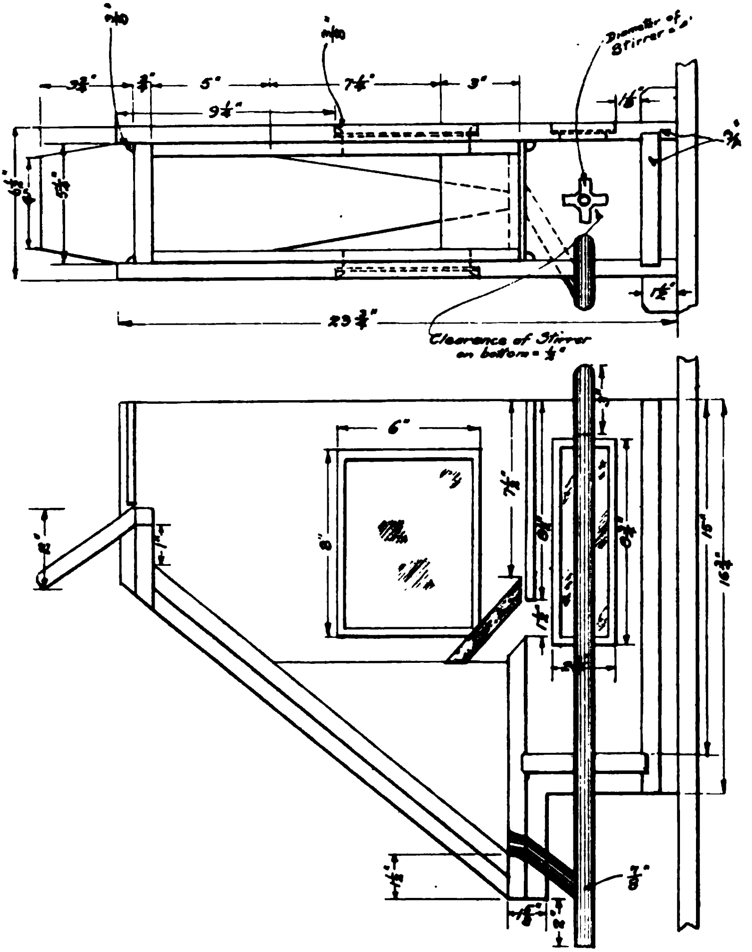
A Mineral Separation type machine after the model described in the Engineering and Mining Journal, Sept. 4, 1915, was then built in our laboratory. The first modification made was to add two inches to the height of the agitator box to lessen the loss due to splashing, to put another agitator to the impellor and to add a glass plate in each side of the spitzkasten for the purpose of judging the nature of the froth. This modification is known as machine No. 1, and was used by Clayton and Peterson in their oil tests.

The next change was to add an air lift to increase the circulation of the pulp. The spitzkasten was next made longer to give the particles of gangue held mechanically in the froth a better chance to settle. This required a larger charge to fill the machine. The width of the spitzkasten was made smaller to reduce the size of the charge. This is shown as machine No. 3 and has an operating volume of 9000 c. c.

In order to keep down the charge required and at the same time get the advantages due to the long spitzkasten, the volume of the spitzkasten was reduced by shaping it as shown in machine No. 5. The air lift was connected to the center of the bottom of the spitzkasten, thereby lessening the amount of accumulation on the bottom of the machine. This machine was used by McCartney in his oil tests. This machine has an operating volume of 3600 c. c. and was built in the School of Mines laboratory at the following costs:



MISSOURI SCHOOL OF MINES
FLOTATION MACHINE No. 1

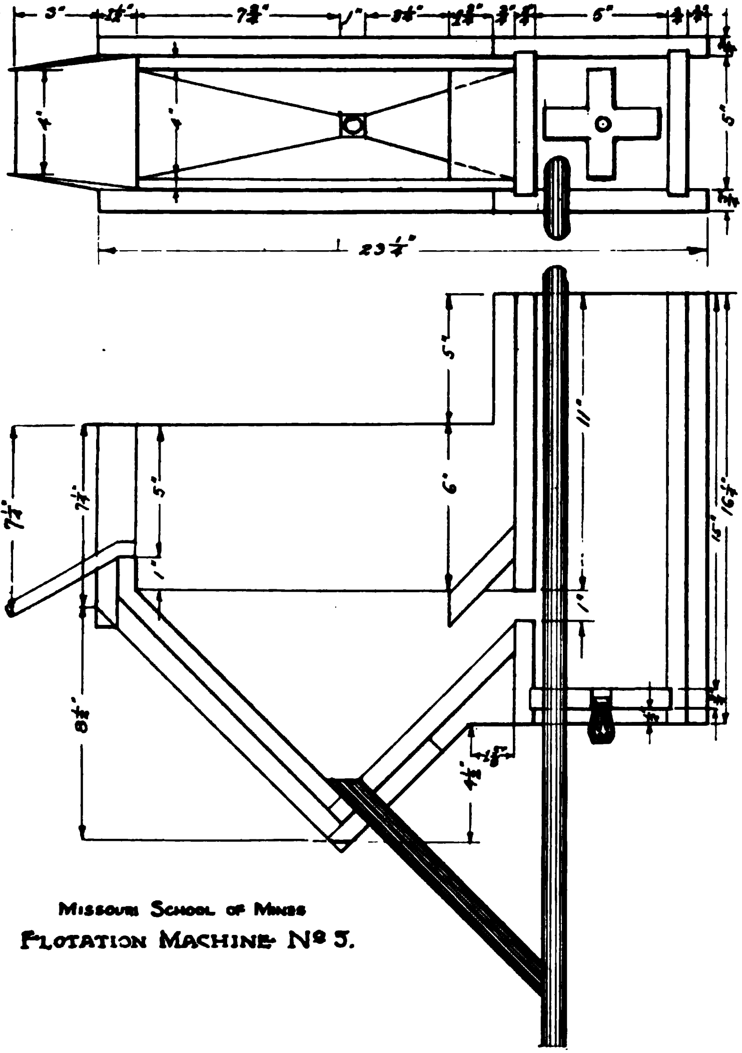


Missouri School of Mines
Flotation Machine Nº 3

Wood	$ 2.50
Labor	5.00
Impellor shaft-material and labor	1.25
Pulley for three speeds	.50
Tinwork	1.50
Bearings, 2 5-8 in. "Dodge" brass split bearings	5.00
Grease cups, 2 No. 000 tiger	.50
Motor, 1-4 H. P. Western Electric, 1700 rpm at 200 volts D. C.	25.85
Belting, 1-4 in. round leather at $2.83 100 ft.	.17
	$42.27

In addition to the several machines already discussed, the Missouri School of Mines laboratory is further equipped with a Janney Laboratory Flotation Machine, the gift of the Utah Copper Company, and with a Callow Standard Pneumatic Testing machine.

The flotation laboratory was not well lighted but we found that the truetint globe made by the Ivanhoe-Regent works of the General Electric Company enabled us to study the nature of the froth in a way comparable with daylight conditions.



MISSOURI SCHOOL OF MINES

FLOTATION MACHINE No 5.

FLOTATION OILS

CHAS. Y. CLAYTON AND C. E. PETERSON

Why is one oil better than another for flotation?

Why do certain oils have the property of selecting certain minerals and not others?

Why do some oils produce an ephemeral froth and others a stiff lasting froth?

Of the large number of oils on the market, why are there so few really good flotation oils?

Is there some fundamental property of an oil which makes it a good flotation agent?

In order to get some definite data on oils for flotation, the writers have undertaken a comparison of the flotation value of different oils under exactly the same conditions. Following somewhat the classification used by chemists, the oils have been arranged in the following groups:

(1) The Fixed Oils.
(2) The Essential Oils.
(3) The Coal Tars.
(4) Coal Tar Derivatives.
(5) Petroleum Products.
(6) Oils from Wood.

The oils from wood we further classify as follows:

(a) Light Oils.
(b) Creosote Oils.
(c) Tar Oils other than Creosotes.

It is realized that these groups overlap to a certain degree, but the idea was to get a classification that would show the source and be easily understood.

The behavior of the oil under test was observed and its flotation value was calculated. The flotation value is defined as the weight of concentrate and metal content obtained in a run of twenty minutes. For example, the flotation value of oil of citronella is given as 35.0-70, which means that in a twenty minute run 35 grams of concentrate was obtained, which analized 70% lead. No attempt was made to determine the total extraction, the idea being to get relative results under the same conditions, so they would be comparable with one another.

The screen analyses were made with Tyler Standard Screens. The ore used was composed of dolomite and galena.

The flotation tests were made in a modified Hoover machine as shown on page (   ) of this bulletin. The capacity of this machine was 4000 grams of water and 800 grams of ore, making a ratio of 5 : 1. The agitator gave 1700 r.p.m. The only variable throughout these experiments is the kind of oil.

SCREEN ANALYSIS for tests D1 to D109

	mesh Thru	mesh On	grams Weight	Per Cent	Cumulative%	%Pb	Total %Pb
1.	65	80	16.25	3.25	3.25	5.34	4.30
2.	80	100	33.50	6.70	9.95	4.49	7.35
3.	100	115	17.70	3.54	13.49	3.35	2.90
4.	115	150	54.53	10.91	24.40	3.69	9.65
5.	150	170	34.40	6.88	31.28	3.47	5.55
6.	170	200	64.50	12.90	44.18	3.17	9.75
7.	200	220	2.00	4.40	44.58	3.43	0.34
8.	220	240	11.92	2.38	46.96	3.065	1.83
9.	240	260	57.70	11.54	58.50	3.47	9.65
10.	260	...	207.50	41.50	100.00	4.63	48.60
			500.00	100.00			100.92

SCREEN ANALYSIS for tests D110 to D162

Thru mesh	On mesh	Weight grams	Per Cent	Cumulative%	%Pb	%of Total Pb
	65	1.0	.20	.20	20.22	.885
65	80	3.7	.74	.94	5.90	.955
80	100	23.6	4.72	5.66	7.62	8.000
100	115	28.9	5.78	11.44	4.65	5.875
115	150	61.2	12.24	23.68	3.45	9.240
150	170	47.7	9.54	33.22	3.00	6.300
170	200	146.4	29.28	62.50	3.22	20.700
200	220	0.0	0.00	62.50	0.00	0.000
220	240	4.2	.84	63.34	3.61	.663
240	250	59.0	11.80	75.14	4.25	10.960
260	...	124.3	24.86	100.00	6.72	36.550
		500.0	100.00			100.128

OILS

In the following experiments the company furnishing the oil is designated by a letter as follows:

A—American Tar Products Co.
B—Local Druggist
C—Eimer and Amend
D—Meyer Bros. Drug Co.
E—Southern States Turp. Co.
F—Southern Cottonseed Co.
G—Florida Wood Products Co.
H—Waters Pierce Oil Co.
I —Standard Oil Co.
J —General Naval Stores
K—Pensacola Tar & Turp. Co.
L—Laclede Gas Co.

M—Public Service Co.
N—Mixed in the Laboratory
O—Barret Mfg. Co.
P—Cleveland Cliffs Iron Co.
Q—United Naval Stores
R—S. D. Warren Co.
S—Georgia Pine Turp. Co.
T—McKesson and Robbins
U—Yaryan Naval Stores
V—F. J. Lewis Co.
W—The Texas Co.

FIXED OILS

No. Test	Oil	Com-pany	Group	Name	Behavior in Flotation	Flotation Value
D5	5	C	I	Olive	Slight skum	3 - 54
D57	16	D	1	Peanut	Slight froth	6 - 71
D7	7	C	II	Rapeseed	Slight film	1.5 - 43
D	14	D	II	Colza	Slight film	2.0 - 41
D111	30	C	II	Rapeseed	As above	3.0 - 45
D	168	C	II	Colza		
D56	17	D	III	Sesame	Slight froth	5 - 67
D78	27	C	III	Corn	Slight froth not recoverable	
D81	31	C	III	Soya Bean	Slight froth not recoverable	
D23	37	C	III	Cottonseed	Small amount thick froth	7 - 64
D108	38	F	III	Cottonseed (crude)	Slight froth not recoverable	
D24	39	F	III	Cottonseed (ref)	Small bubbles—few	5 - 67
D21	40	F	III	Cottonseed (resd)	Extra large heavy bubbles out of place here	6 - 23
D2	2	C	IV	Linnseed (raw)	Fair skum—no froth	12 - 74
D3	3	C	IV	Linnseed (Boiled)	No froth—film	5 - 53
D79	28	C	IV	China Wood	Not recoverable froth	
D83	33	C	IV	Poppy seed	Not recoverable froth	
D1	1	C	V	Castor	Thick skum	20 - 52
D	116	B	V	Crot'n(Ol'mTiglin)	No action	
D4	4	C	VIII	Neatsfoot	Thin oil film	3 - 25
D		B	VIII	Lard Oil	As above	6 - 30
D80	29	C	X	Menhaden (Tech)	Not recoverable froth	
D82	32	C	X	Menhaden (Pure)	Not recoverable froth	
D		C	X	Whale	Small amount small bubbles little selection	2.5 - 11.4
D95	46	B	X	Codliver	Small amount small bubbles little selection	3 - 58

PETROLEUM PRODUCTS

D85	36	C	Paraffin	Oil film—not recoverable	
D87	50	B	Kerosene	Oil film—not recoverable	
D36	52	H	Fuel Oil	Oil film small	11.0 - 68
D37	53	I	Atlanta Red	Oil film small	1.5 - 47
D38	54	I	Diamond Refined	Oil film small	4 -47
D39	55	I	Standard Heavy Eng	Oil film small	3 - 42
D46	61	I	S. F. Cylinder Oil	Failed to emulsify	1 - 22
D47	62	H	Cushing's Oil	Failed to emulsify	3 - 36
D48	63	H	Black Oil	Failed to emulsify	3 - 26
D136	152	I	Calol A	Light froth—small bubbles	1 - 20
D137	153	I	Calol B	Light froth-small bubbles	1 - 24
D138	154	I	Calol C	Light froth—small bubbles	0.5 - 25
D	173	H	Fuel Oil		

ESSENTIAL OILS

No. Test	Oil.	Company	Name	Behavior in Flotation	Flotation Value
D90	41	B	Wine	Light stiff bubbles	15.0 - 64
D91	42	B	Male Fern	Heavy stiff bubbles	21.0 - 44
D92	43	B	Pennyroyal	Small bubbles—stiff	34.0 - 64
D93	44	B	Cloves	Small bubbles—light froth	35.0 - 70
D94	45	B	Citronella	Large quantity small ephemeral bubbles	30.0 - 70
D96	47	B	Sassafrass	Thin small bubbles	11.0 - 54
D97	48	B	Origanum	Small ephemeral bubbles	16.0 - 54
D98	49	B	Amber	Large stiff bubbles	13.0 - 50
D	110	B	Bitter Almond	Small frail bubbles	7.0 - 54
D116	111	B	Cumin-Oleum Cuminis	Large amount small bubbles	23.0 - 65
D117	112	B	Mustard-Oleum Sinapis Vol.	No action	
D120	113	B	Cubeb-Oleum Cubebae	Small watery bubbles	5.0 - 50
	114	B	Cajuput		
D119	115	B	Wormwood-Oleum Absinthum	Large bubbles eph.	4.0 - 49
	116	B	Croton-Oleum Tiglin	See Fixed Oils	
	117	B	Wormseed		
D121	118	B	Bergamont-Oleum Bergamelon	Heavy froth—large bubbles	20.0 - 39
D115	119	B	Cassia-Ol'mCinnamonium	Small bubbles frail	23.0 - 65
D131	124	B	Spearmint	Small bubbles tough	50.0 - 44
D131	125	B	Rue	Small amount of very small bubbles	7.0 - 64
D134	126	B	Verbena	About 1-2 in. bubbles stiff	36.0 - 67
D130	127	B	Black Pepper	Small bubbles	22.0 - 54
D133	128	B	Sandalwood	Very small bubbles—eph.	12.0 - 59
D136	129	B	Sweet Orange	Light froth tough	7.0 - 68
	163	T	Citronella	Large quantity small bubble froth	25.0 - 64
	181	C	Terpineol	Watery small bubble froth	11.0 - 13
	183	C	Oil of Camphor	Same as above better select	19.0 - 21

THE COAL TARS

D70	79	A	No.3 Crude Gas House Tar	No froth apparently a good selector	No	No
D71	80	A	No.4 Crude Water Gas Tar	As above	No	No
D72	81	A	No.5 Crude Coke Oven Tar	As above	No	No
D76	83	L	Coal Tar fram Gas Oven	As above	No	No
D77	84	L	Water Gas Tar	As above	No	No
D78	85	M	Coal Tar	As above	No	No
D162	162	S	Cannel Coal Tar	Behavior more like a petroleum product	No	No

COAL TAR DERIVATIVES

D10	12	D	Toluol	Very thin froth	4.0 - 55
D	12a	D	Xylol	Very thin froth not recoverable	
D27	25	D	Cresylic Acid	Copious small bubble froth ephemeral	32.0 - 71
D28	26	D	Creosote	Heavy black froth—stiff	24.0 - 74
D68	77	A	No. 1 Creosote	No froth	5.0 - 60
D69	78	A	No. 2 Mixture creosote and refined tar	Large bubbles—stiff	37.0 - 89

No. Test	Oil	Company	Name	Behavior in Flotation	Value
D75	82	A	No.6 Oil from Water Gas Tar	No frothing action—skum	9.0 - 62
D102	107	O	Flotation Oil No. 1	Light watery ephemeral fro.	13.0 - 43
D103	108	O	Flotation Oil No. 2	Light watery ephemeral fro.	8.0 - 47
D104	109	O	Flotation Oil No. 3	Light watery ephemeral fro.	5.0 - 50
D	166	S	Flotation Oil No. 1	No tests made	
D	174	V	F. J. L. No. 3	No tests made	
D	175	V	Acid Oil	No tests made	
D	176	V	Cresylic Acid	No tests made	
D	180	X	Flotation Oil No. 609	Small bubble froth—eph.	3.5 - 19
		C	Creosote white	Small bubble froth—copious and ephemeral	16. - 24

WOOD OILS—LIGHT OILS APPROACHING ESSENTIAL OILS

D9	9	B	Turpentine	Thin ephemeral froth	9.5 - 50
D109	10	E	Turpentine	Thin ephemeral froth	4.0 - 26
D110	11	E	Turpentine	Thin ephemeral froth	2.0 - 50
D61	70	K	CrudeWoodTurpentine No. 80	Small bubble ephemeral froth—similar to above	5.0 - 61
D63	72	K	Crude Wood Turpentine No. 75	As above	4.0 - 55
D64	73	K	Special Pine Oil No. 1580	As above	5.0 - 57
D65	74	K	Crude Wood Oil	Look under tar oils	18.0 - 52
D50	66	J	Pine Oil No. 6	Small ephemeral bubbles	16.0 - 69
D66	75	K	Pure Pine Oil	Small ephemeral bubbles	13.0 - 72
D146	142	Q	H-Pine Oil	Small ephemeral bubbles	5.0 - 60

WOOD OILS—WOOD TAR OILS

D143	136	J	No. 7 Spec. Pine Tar	Large stiff bubbles—large quantity	22.0 - 39
D156	65	J	No.7 S.S.C.P.T.Oil	Large bubbles, stiff froth	19.0 - 35
D144	131	G	Comm. Tar Oil	Large stiff bubbles	17.0 - 39
D152	146	K	No.90 Tar Oil Ref.	No results very slight froth	No No
D153	147	K	No. 750 Spec. Tar Oil	Same as above	
D58	67	G	Ref. Tar Oil	Large amount small ephemeral bubbles	21.0 - 71
D35	51	G	Comm. Tar Oil	Large bubble stiff—large amount	28.0 - 55
D49	64		Tar Oil	Failed to emulsify	No No
D	74	K	Crude Wood Oil	Large stiff bubbles—large quantity	18.0 - 52
D	132	G	Tar	Failed to emulsify	No No

WOOD OILS—WOOD CREOSOTES

No. Test	Oil	Company	Name	Behavior in Flotation	Flotation Value
D129	123	B	Crude Beech Creosote	Large watery bubbles	18.0 - 40
D126	122	B	Pure Beech Creosote	Large watery bubbles	19.0 - 62
D141	133	P	Wood Creosote No. xx	Small bubbles stiff froth	19.0 - 64
D142	134	P	Wood Creosote No. 3	As above seems ephemeral	14.0 - 64
D	135	P	Spec. Flo. Oil—	Small bubbles stiff froth	4.0 - 53
D59	68	K	Ref. Wood Creosote	Large stiff bubbles—large amount	23.0 - 64
D60	69	K	Crude Wood Creosote	Large fairly stiff bubbles	30.0 - 68
D150	143	P	Wood Creos. No. 1	Large fairly stiff bubbles	
D	148	K	Ref. Wood Creos.		
D	161	S	Creosote Oil		

MISCELLANEOUS WOOD PRODUCTS

D15	19	B	Pyroligneous Acid	No recoverable froth	No No
D139	130	G	Pyroligneous Acid	No recoverable froth	
D151	145	R	Phenolic Acid	Heavy stiff froth—rick Pb.	
D	149	S	Australole		

ROSIN OILS AND BALSAMS

	120	B	Balsam Sopiaba	Large amount medium sized tough bubbles	22.0 - 12
	121	B	Balsam of Reru	Very light froth—large bubbles	4.0 - 32
	34	C	Rosin Oil	Small amount large bubbles—froth	15. - 49
	35	D	Rosin Oil	Heavy stiff large bubble froth	22.0 - 37
	20	B	Cedar Wood	Heavy stiff large bubble froth	28. - 48
	21	B	Cedar Wood	Little or no froth—skum	9. - 72

FATTY ACIDS

D17	22	C	Oleic Acid	Large bubble froth—stiff	77. - 13
	184	C	Butyric Acid	Small bubbles not similar to oleic	No No

MISCELLANEOUS

D14	18	B	Amyl Acetate	Small bubble ephemeral froth	15 - 45
	182	C	Terebene	Small watery bubbles	3.5 - 11
	164	C	Sodium Oleate	Copious froth but no selection	
	165	C	Sodium Resinate	Same as above	

THE FIXED OILS

The Fixed Oils may be classified as "inactive" oils as far as frothing ability is concerned. They all form a slight skum on the surface of the water, which when large enough to handle, shows fair selection for lead. The Fixed Oils are all of a greasy or lubricating nature as distinguished from the solvent types of oils such as turpentines and pine oils and all have the stiffness or "body" which seems to prevent their emulsifying or mixing with the water.

PETROLEUM OILS

The Petroleum Oils give practically no froth and as a class show poor selection for lead. These oils are not miscible with the water, but form a slight skum on the surface, which is difficult to separate from the water.

THE ESSENTIAL OILS

The Essential Oils give a good froth and show good selective properties. The froth is ephemeral and usually consists of small bubbles. An ephemeral froth with small bubbles will give a clean concentrate because the possibility of contamination by suspended slimes in the water is lessened in proportion to the thinness of the bubble film and this is probably one reason that the Essential Oils give such clean concentrates. These oils are miscible with the water to a large extent, and this tendency undoubtedly aids their frothing ability.

COAL TARS

The various coal tars because of their extreme viscosity do not show any action in flotation unless they have been subjected to a thorough agitation outside of the flotation cell proper. Water gas tar or mixtures of water gas tar and gas retort tar are generally less viscous and give better results. Coal tars can be readily thinned by mixing with cresylic acid or coal tar creosote and when so mixed give an oil that will produce a good stiff froth and select depending upon the ratio of tar to acid. The higher the acid content the more ephemeral is the froth and the better the selection.

COAL TAR DERIVATIVES

The various oils obtained by destructive distillation of coal tars have vastly different physical and chemical properties, and as it would be expected different flotation properties. Cresylic acid is the best product from a flotation standpoint, giving a copious ephemeral froth with a high selection for galena. The coal tar creosotes give a thicker stiffer froth and also show poorer selection, probably due to the fact that the oil film is thicker and would carry more suspended slimes. The flotation oils falling in this group generally are the tar acids with more or less tarry matter. The presence of tar generally tends to produce a stiffer but a lower grade froth. Froths obtained with these oils are usually large bubbles, i. e., from 1-2 to 2 in. in diameter.

PINE OILS

Into this group are placed the lighter oils obtained from distillation of wood gums or wood. These oils resemble in action the essential oils and also contain compounds commonly contained in essential oils. The oils with the exception of the second grade turpentine show a selective action above the average, namely, giving a 50 to 72% lead concentrate. The pure pine oil gives the highest grade concentrate and also the largest quantity of froth. As this oil is contaminated with turpentine, the tener of the concentrate falls off and the quantity also decreases. Froths from the pure yellow pine oils are copious, free running and ephemeral, and the bubble size is small.

THE WOOD TAR OILS

The Wood Tar Oils are the heavy oils other than the creosotes occuring in the destructive distillation of wood. They all give a stiff froth, with large bubbles, and show a poorer selection than the average. The poorness of selection is probably due to a large extent to the mechanical contamination of the froth by the "dirty" slime water, which with the oil makes the thick bubble films.

THE WOOD CREOSOTES

The Wood Creosotes give a heavy stiff froth with large bubbles and good selection. They give a slightly less amount of froth than Wood Tar Oils, and the total weight of concentrate made is less. showing a thinner oil film and therefore one that will give a cleaner concentrate.

ROSIN OILS AND BALSAMS

These oils were placed in the same group because of the fact that Allen so places them in his "Organic Analysis." These oils give froths composed of large bubbles which are thick filmed and tough, resembling the wood tar oils. With the exception of the crude cedar wood oil, the froths show only fair selection with respect to galena.

FATTY ACIDS

The only acids in this group that were tested were Oleic and Butyric acid. Their action in flotation was in no way similar.

oleic giving a large quantity of large bubble froth while butyric acid gave a very small amount of small bubble froth. Neither of the oils showed any selective action toward galena.

GENERAL CONCLUSION

In general, it seems that the oils which are miscible with the water are the frothing oils and theoretically, at least, the oil which will give the ephemeral, small bubble froth will give the cleaner concentrate when compared with an oil which forms a thick stiff froth, but the recovery may be greater in the second case. To get a clean concentrate, therefore, it may be necessary to sacrifice recovery, and vice versa, when using only one oil. With more than one oil a new problem comes in. From a small amount of preliminary work done, it was found that when mixing two oils in varying amounts, the frothing and selecting properties of the mixture did not always lie between the values found for the separate oils, tending to show the possibility of the formation of a chemical compound rather than a simple physical mixture, or at any rate this would show that the physical properties of each were considerable modified by the presence of the other..

After studying the various oil groups and their flotation results, it can be said that, in general, the oils in the various groups behave in a similar manner in flotation. Even though this fact is granted a careful study of the physical and chemical properties of the various oils does not lead to a solution of the problem, what property or combination of properties of an oil give it a value to flotation.

Frothing Oils that show a marked selective action toward galena:

Name	Flo. Value wt. %Pb.	grams Pb. Flo. Value
Creosote (Coal Tar)	24.0 - 74	16.76
Pure Pine Oil	13.0 - 72	9.36
Cresylic Acid	32.0 - 71	22.73
Refined Tar Oil	21.0 - 71	14.91
Oil of Cloves	35.0 - 70	24.50
Oil of Citronella	30.0 - 70	21.00
Pine Oil No. 6	16.0 - 69	11.04
Oil of Sweet Orange	7.0 - 68	6.86
Oil of Verbena	36.0 - 67	24.12
Oil of Cumin	23.0 - 65	14.95
Oil of Cassia	23.0 - 65	14.95
Pennyroyal	34.0 - 64	21.76
Oil of Citronella (2nd)	25.0 - 64	16.00
Oil of Wine	15.0 - 64	9.60

A study of the above data brings out the fact that as a class the essential oils give the best flotation on this certain dolomitic lead ore. While Coal Tar Creosote gives the highest grade concentrate, Oil of Cloves would give the highest extraction as indicated by the grams of lead obtained in a 20 minute test period.

EXPERIMENTS ON A JOPLIN SLUDGE

W. H. McCartney

MACHINE USED. A development of the Hoover type of the Minerals Separation testing machine was used. This machine is shown in cross-section in this bulletin, Missouri School of Mines Flotation Machine No. 5.

CHARGE.	Water	3200	grams
	Ore	400	grams
	Oil	4	drops

TIME OF RUN. Fifteen minutes.

VARIABLE. Kind of oil used.

ORE USED. Slime from a Joplin Sludge Pond. It assayed 1.75% Zinc and all passed through a 48 mesh screen, 86% passing thru 150 mesh.

RECORDED DATA. In tabulating the data the oils were arranged in certain groups, behavior of oils noted, and the flotative value recorded. The 1st figure in the value given is the weight of froth obtained expressed in grams and the 2nd figure is the percentage of zinc in the froth.

FIXED OILS

Name	Behavior in Flotation	Flo. Val.
Olive	No froth, some min. in float small amount in conc.	1.4 - 24.2
Rapeseed	Skummy froth carrying a good amount of mineral	3.0 - 31.1
Corn	Small bubbles, skummy froth	4.3 - 19.9
Soya Bean	Thin film carrying small amount of mineral	1.1 - 18.9
Cottonseed	Light rich skummy froth not lasting	5.6 - 43.7
Cottonseed (crude)	No froth	2.0 - 25.4
Cottonseed (resd)	Large amount of fair froth	9.6 - 20.7
Linseed (raw)	No froth	.5 - 30.8
Linseed (Boiled)	Small skummy froth	1.4 - 25.0
China wood	No froth	1.4 - 24.2
Poppy seed	Very light froth—small bubbles approaching skum	0.7 - 24.0
Castor	Skum formed	1.3 - 26.6
Neatsfoot	No froth—small skum	2.2 - 24.3
Menhaden (Tech)	Small bubbles skummy froth	2.2 - 27.35
Menhaden (Pure)	Very light film of oil	1.1 - 23.9
Whale	Small amount small bubbles—little selection	2.5 - 11.4
Codliver	Small amount of small bubbles—little selection	

PETROLEUM PRODUCTS

Name of Oil	Behavior in Flotation	Flo. Val.
Fuel Oil	Very small bubble, forming a skum-like froth	1.3 - 15.8
Atlanta Red	Small amount of skum	0.5 - 20.0
Diamond Refined	Small amount of skum	1-1 - 9.8
Standard Heavy Eng.	No recoverable skum or froth	
S. F. Cylinder	Very small amount of skummy froth	5.4 - 9.2
Cushing Crude	Thin ephemeral small bubbles very small quantity	1.6 - 20.2
Black Oil	Thin film of oil formed	1.0 - 34.0
Paraffin Oil	Slight amount of skum	5.2 - 24.6
Kerosene	Thin film, not recoverable	

COAL TARS

Water Gas Tar	Slight skum	1.8 - 43.
Gas Oven Tar	Thin film	.7 - 22.
Crude Gas Hause Tar	Thin oily skum	1. - 35.
Crude Water Gas Tar	Same as above	2.3 - 32.
Crude Coke Oven Tar	Same as above	1.4 - 13.

COAL TAR DERIVATIVES

Coal Tar Creosote	Small skum of mineral	.5 - 22.4
Creosote and Ref.Tar	Small bubble froth	3.4 - 45.9
Oil from Water G. T.	Thin film of oil	.7 - 22.0
Cresylic acid	Good small bubble ephemeral froth	9.5 - 43.
Coal Tar Creosote	Light small bubble froth grading into skum	3.1 - 34.7
Barrets Flo. No. 1	No froth	.4 - 15.9
Barrets Flo. No. 2	No froth	1.4 - 25.5
Barrets Flo. No. 3	Small bubble ephemeral froth	2.5 - 45.3

FLOTATION OILS AND MISCELLANEOUS

G.N.S. No. 8	Medium bubbles fairly large froth	3.2 - 18.4
G.N.S. No. 17	Small bubbles—good amount ephemeral froth	2.4 - 18.5
G.N.S. No. 18	Large bubble froth	24.2 - 24.6
G.N.S. No. 22	Fair amount of medium sized bubbles	2.0 - 32.
G.N.S. E - 2	Small bubbles froth	2.3 - 34.5
Pine Oil No. 6	Small frail bubbles	7.9 - 50.
Ref. Tar Oil No. 9	No froth, a skum	3.2 - 45.9
Ref. Wood Creosote	Small amount of small bubbles	12.8 - 34.7
Crude Wood Creosote	Medium size bubbles, stiff	10.9 - 27.5
Crude Wood Turps No. 80	Small ephemeral bubbles	2.0 - 22.
Crude Wood Turps. No. 75	As above	2.9 - 21.4
Special Rosin Oil	Small frail bubbles	1.5 - 16.4
Special Pine Oil No. 1580	Medium size strong bubbles	35.5 - 14.7
Pure Pine Oil No. 5	Small tough bubbles	3.7 - 23.9
Eucalyptus	Small frail bubbles	4.3 - 48.3
Oleic Acid	Small amount of small bubbles	8.85-33.7

Arranging the Oils in the order of their Frothing ability we have:

Special Pine Oil No. 1580	35.5 grams - 14.7 % Zn
Gen. Naval Stores No. 18	24.2 grams - 24.6 % Zn
Ref. Wood Creosote. Pensacola No. 200	12.8 grams - 34.7 % Zn
Crude Wood Creosote. Pensacola No. 400	10.9 grams - 27.5 % Zn
Cottonseed Residue. Southern C. Oil Co.	9.6 grams - 20.7 % Zn
Cresylic Acid	9.5 grams - 43. % Zn
Oleic Acid	8.85 grams - 33.7 % Zn

Arranging the Oils in the order of their selecting ability, we have:

G.N.S. Pine Oil No. 6	50.0 % Zn conc. - 7.9 grams
Eucalyptus Oil	48.3 % Zn conc. - 4.3 grams
Ref. Tar Oil No. 9	45.9 % Zn conc. - 3.2 grams
Creosote and Refined Tar	45.9 % Zn conc. - 3.4 grams
Barrets Flo. Oil No. 3	45.3 % Zn conc. - 2.5 grams
Cresylic acid	43.0 % Zn conc. - 9.5 grams

In comparing the flotation results of the various oils as determined by McCartney with those determined by Clayton and Peterson it can be seen that the general behaviour of the Fixed Oils, Petroleum Products, Coal Tars, and Coal Derivatives is about the same. In neither set of experiments did the first three classes of oils give any appreciable frothing value although showing a selective action for galena. The fact that the quantity of froth and its metal tener in McCartney's work are low is probably due to the fact that the metal tener of the original flotation feed was very low.

DIELECTRIC CONSTANTS AND FLOTATION VALUES OF OILS

Dielectric Constants were determined by Dr. Herman Schlundt, University of Missouri, and the Flotation Values by Chas. Y. Clayton and C. E. Peterson, January, 1916.

Oil	Behavior in Flotation	Flotation Value	Prelim. Dielecric Constant Approx.	
Citronella	Frothing, giving an ephemeral small bubble froth	30.0-74	4.38-4.83	
Orange Peel	Thick pulpy froth	21.0-76	2.0 -2.35	
Pine Oil	Frothing, giving an ephemeral small bubble froth	16.0-69	4.42	
Lemon	Frothing, giving a thin ephemeral froth	25.0-68	2.95	
Cresylic acid	Frothing, giving a more lasting large bubble froth	32.0-71	9.80	
G.N.S. No. 8	Frothing, giving large stiff bubbles	32.0-61	4.36	hydrox.
G.N.S. No. 17	Frothing, giving large thin bubbles	32.0-75	12.0	approx. hydrox.
G.N.S. No. 18	As above	35.0-71	9.8	" "
G.N.S. No. 22	Frothing, giving medium sized ephemeral bubbles	19.0-68	3.05	
1-2 Cresylic 1-2 Castor	Non-frothing—gives heavy skum of small bubbles	24.0-73	4.33	conducts
Peach Kernel	Frothing, small bubbles	7.0-54	2.86	
Castor	Non-frothing—skum like	20.0-52	3.40	
Crude Wood Turpentine	Frothing, giving an ephemeral small bubbles froth	5.0-61	4.15	
Olive	Slight skum formed	3.0-54	2.76	
Cottonseed	Small amount of light bubbles	5.0-67	3.00-2.71	
Corn	Practically inactive		3.00-2.6	
Soya Bean	Practically inactive		2.96	
Rosin oil	Frothing, giving a heavy stiff froth	22.0-37	2.95	
Black Grease	Frtohing, giving large stiff bubbles	16.0-23	3.12-2.78	
Oleic acid	Frtohing, giving large stiff bubbles	77.0-13	2.7 -2.35	
Sperm	Thin film formed	4.0-55	2.90	
Codliver	Thin film formed	3.0-58	2.85	
Lubricating	Thin oil film formed	1.0-22	1.60-2.15	
Cylinder	Thin oil film formed	4.0-47	2.47	
Crude Petrol.	Thin oil film formed	3.0-36	2.28	
Water Gas Tar	Inactive, failing to emulsify	No	2.78	
Coal Tar	Inactive, failing to emulsify	No	3.49	

The data above shows that oils giving good flotation results have high dielectric constants. Lemon and Orange Peel oil are exceptions.

THE QUANTITATIVE EFFECT OF A FROTHING AND A NON-FROTHING OIL, BOTH HAVING A SELECTIVE ACTION TOWARD GALENA

Chas. Y. Clayton and C. E. Peterson

The following experiments were made for the purpose of determining the effect of varying the quantity of oil used with a given charge in flotation.

The experiments were performed in Flotation Machine No. 1, using 800 grams of a dolomitic lead ore and 4000 grams of water. The duration of each test was twenty minutes. All factors were constant except the amount of oil.

In test No. 1 Oil of Citronella, giving an ephemeral froth and showing good selective action toward galena, was used.

In test No. 2 a mixture composed of

1 part—Cresylic Acid
2 part—Refined Cottonseed
2 part—Castor
2 part—Coal Tar Creosote
2 part—G.N. S.Flo. Oil No. 20

giving a small bubble skum and showing a good selective action toward galena, was used.

RESULTS, TABULATED

TEST NO. 1

Amt. Oil drops	Concentrate Wt.	%Pb.
4	16.7	79.1
5	14.4	79.3
6	16.11	79.2
7	20.5	79.3
8	23.3	79.8
9	24.2	79.3
10	26.7	80.0
15	28.1	80.0
20	30.1	80.0
25	39.7	74.24
40	32.7	77.4

TEST NO. 2

Amt. Oil drops	Concentrate Wt.	%Pb.
1	2.0	57.4
2	3.4	58.8
3	10.1	71.2
4	10.3	76.4
5	13.9	69.2
10	19.2	69.7
15	21.5	69.8
20	26.3	66.0
25	48.2	63.6
30	40.4	58.5
40	36.4	62.1

These results are also shown in curves.

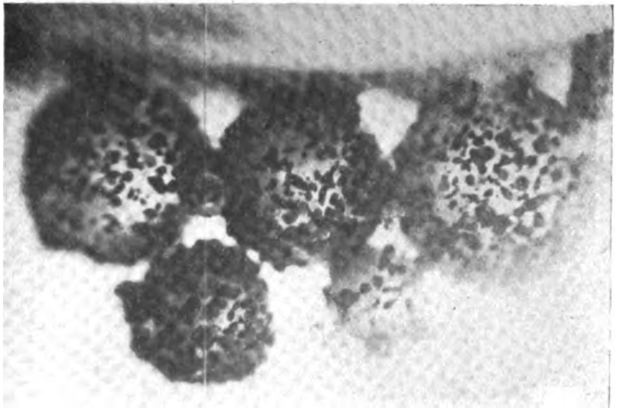
These experiments show that the tener of the concentrate, after a certain quantity of oil is reached, decreases as the quantity of oil increases. The change in the tener of the concentrate is more marked where the oil mixture was used than where oil citronella was used.

They also show that the quantity of concentrate apparently reaches a maximum and then declines as the amount of oil increases.

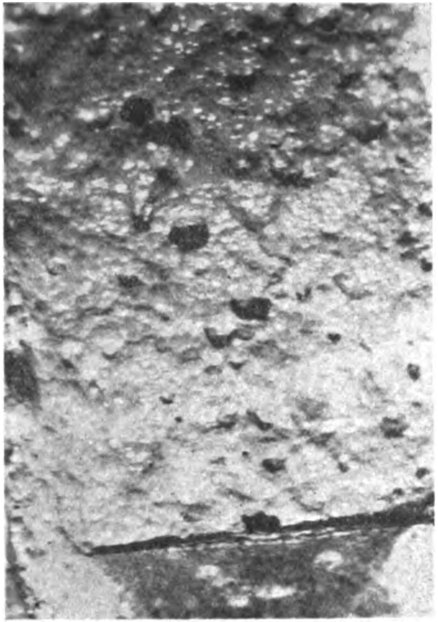
PHOTOGRAPHS OF FLOTATION BUBBLES

Chas. Y. Clayton

Photographs Nos. 1 and 2 show cross-section view of bubbles nder water. Photographs Nos. 3 to 8 inclusive show the froth n a small experimental machine as viewed from above.

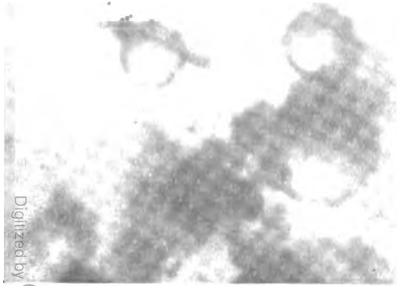


No. 1—Showing bubbles of a Pine Oil froth to which are adhering particles of Cassiterite. Magnified 40 x.



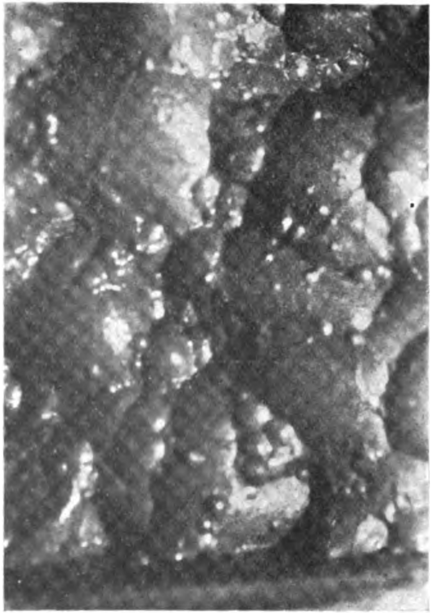
NO. 8 WOOD CREOSOTE FROTH.

Same as No. 7 after adding Oil from Water Gas Tar. Note how the froth has been "killed."



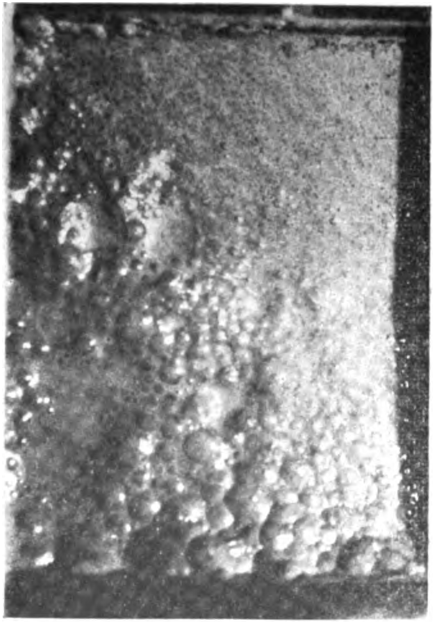
NO. 2 PINE OIL NO. 6.

Showing bubbles lifting small particles of galena. Magnified 40 x.

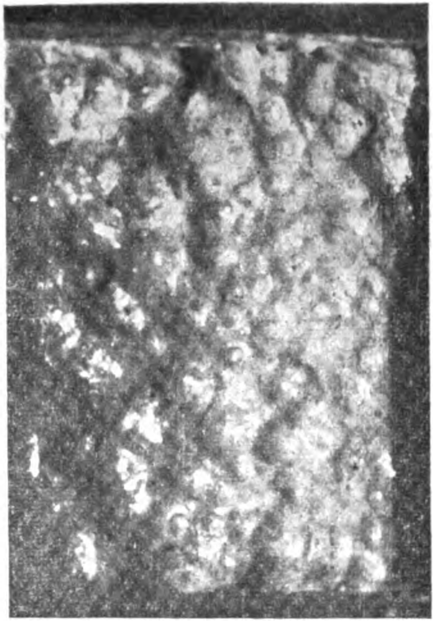


NO. 3 CRESILIC ACID FROTH.

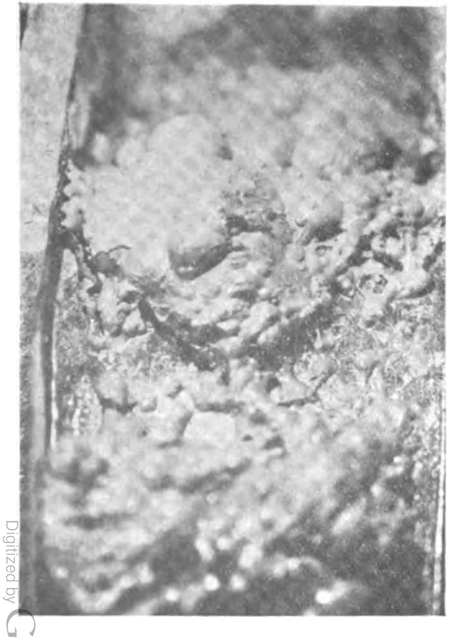
This photograph was made after stopping impellor, so bubbles have coalesced somewhat. Froth is ephemeral and of thin bubble film.



NO. 4 COAL TAR CREOSOTE FROTH.
Thin filmed, somewhat ephemeral, bubbles. Max. diameter about 1-2 in.

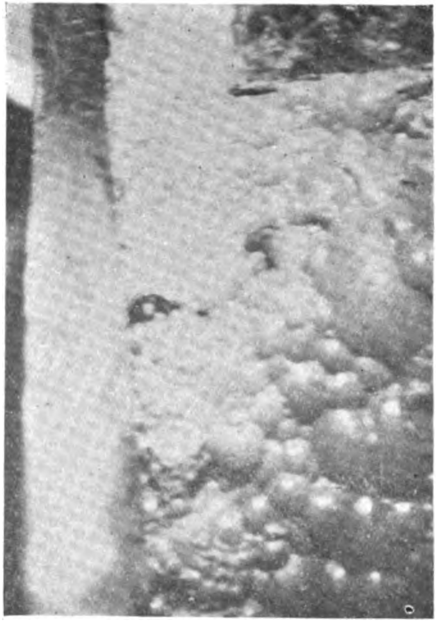


NO. 5 PINE OIL NO. 6 FROTH.
Small ephemeral bubbles which give a skum-like froth after stopping impellor.



NO. 6 WOOD CREOSOTE FROTH.

Large, stiff, dry bubbles, about 1 1-2 in. in diameter. Characteristic of wood creosotes. This shows correct oiling. Note No. 7.



NO. 7 WOOD CREOSOTE FROTH.

This shows thin filmed, watery bubbles of about 3-4 in. diameter, a result of excessive amount of oil. Same oil as in No. 6.

SCREEN ANALYSIS OF FLOTATION CONCENTRATES

Chas. Y. Clayton

In the following experiments, flotation concentrates obtained from previous tests were diluted with water and run thru a set of Tyler Standard screens. The material on each screen was dried and assayed.

In making the screen analysis, the dilute pulp passing thru 260 mesh was placed in large pans and agitated by stirring with a spatula, then allowed to settle for about five minutes, when the water and unsettled slime was poured off and dried. The material poured off is classed as 260_0, while material remaining in the pans is classed as 260_S.

The concentrates for experiments 1 to 4 inclusive were obtained on a standard Callow pneumatic machine, that for experiment 5 in a mineral separation machine and that for experiment 6 from an actual flotation plant. The pulp ratio was 5 to 1. The oils used for obtaining the concentrates were as follows:

Experiment 1: Oil from water gas tar, American Tar Products Co., four parts and a solution of Fairbanks glycerine soap (5 grams soap to 100 c.c. water) one part.

Experiment 2: Pine oil No. 6, General Naval Stores Co.

Experiment 3: Oil of Citronella, McKisson & Robbins.

Experiment 4: Flotation oil No. 17, General Naval Stores Co.

Experiment 5: Same as Experiment 4.

Experiment 6: Creosote oil No. 2, Cleveland Cliffs Iron Co.

The quantity of oil used was not recorded; the amount was regulated to give a good froth.

The original concentrates were obtained from a dolomite lead ore.

The results are given in the following tables:

Data. Experiment No. 1

Thru mesh	On mesh	Ave.dai. m|m	wt. grams	% Pb	grams PbS	grams by diff. gangue	% total gangue
65	80	0.187	25.70	79.4	23.5	2.2	1.26
80	100	0.161	40.90	79.2	37.3	3.6	2.06
100	115	0.135	44.40	78.4	40.0	4.40	2.52
155	150	0.114	25.90	74.2	22.1	3.80	2.18
150	170	0.096	26.00	75.4	22.5	3.50	2.01
170	200	0.081	13.30	70.2	10.7	2.60	1.48
200	260	0.065	22.50	68.2	17.6	4.90	2.81
260_S			117.90	60.4	82.0	35.90	20.5
260_O			143.20	18.05	29.65	113.50	65.90

Data. Experiment No. 2

Thru mesh	On mesh	Ave.dai. m|m	wt. grams	% Pb	grams PbS	grams by diff. gangue	% total gangue
65	80		5.00	63.4	3.67	1.33	0.72
80	100	as	19.50	75.4	16.35	3.15	1.70
100	115	above	6.7	74.0	5.72	1.00	0.54
115	150		15.6	76.0	13.69	1.90	1.05
150	170		10.4	76.4	9.17	.66	0.36
170	200		21.0	74.2	18.00	3.00	1.62
200	260		17.2	70.4	13.98	3.22	1.74
260 s			111.0	75.0	95.45	15.55	8.40
260 o			234.2	29.2	78.95	155.25	84.00

Data Experment No. 3

65	80	0.187	21.0	76.0	18.43	2.57	1.18
80	100		58.3	77.6	52.23	6.07	2.79
100	115		53.3	78.2	48.12	5.18	2.38
115	150		30.0	65.6	22.72	7.28	3.35
150	170		35.0	67.8	27.40	7.60	3.50
170	200		35.5	64.7	26.52	9.98	4.13
200	260		43.1	55.7	27.72	15.38	7.08
260 s			170.0	67.0	129.40	40.60	18.70
260 o			178.0	26.9	55.28	122.72	56.40

Data Experiment No. 4

		wt. grams	% Pb	% Zn	grams Pbs-ZnS	grams gangue by diff.	% total gangue
65	80	13.2	4.8	32.0	6.38	6.82	3.92
80	100	29.5	26.8	33.4	23.32	6.28	3.6
100	115	33.0	39.8	22.2	24.95	8.05	4.6
115	150	13.5	36.2	19.4	9.14	4.36	2.5
150	170	19.2	40.2	13.2	12.32	6.88	3.95
170	200	39.1	47.6	9.7	26.55	12.55	7.22
200	260	33.2	46.4	9.3	21.90	11.29	6.48
260 s		111.37	40.4	9.25	91.44	19.93	11.45
260 o		336.70	26.26	7.95	138.90	97.80	55.80

Data Experiment No. 5

Thru mesh	On mesh	Ave.dai. m|m	wt. grams	%Pb	grams PbS	grams gangue by diff.	%total gangue
65	80		00.00	00.00	00.00	0.00	0.00
80	100		4.40	40.00	2.22	1.78	0.22
100	115		27.1	76.2	23.7	3.4	0.43
115	150		36.9	72.2	30.6	6.3	0.80
150	170		25.0	77.8	22.36	2.64	0.35
170	200		34.6	76.4	30.8	3.8	0.48
200	260		35.5	71.8	29.3	6.2	0.49
260_S			21.5	80.2	19.8	1.7	0.21
260_O			1080.0	25.8	320.4	759.6	96.6

Data. Froth from a Mill

65	80		00.00	0.0	0.0	0.0	0.00
80	100		6.1	41.4	2.9	3.2	0.79
100	115		0.0	0.0	0.0	0.0	0.00
115	150		4.6	33.4	1.8	3.8	0.95
150	170		5.15	31.6	1.9	3.6	0.89
170	200		0.0	0.0	0.0	0.0	0.0
200	260		7.5	46.8	4.0	3.5	0.86
260_S			105.0	62.4	75.4	29.6	7.3
260_O			834.0	49.3	472.5	361.5	89.2

These experiments show that the percentage of gangue material floated is the greatest for the finest material. In experiment No. 1 the material thru 260_O assays only 18.05% lead and contains 65.90% of the gangue floated. Experiment No. 2 gave material thru 260_O with 29.2% lead and containing 84% of the total gangue material floated. The same material in experiment No. 3 assayed 26.9% lead and contained 56.40% of the total gangue floated. In experiment No. 4 this product assayed 26.26% lead and contained 55.80 of the total gangue. In experiment No. 5 this product assayed 25.8% lead and contained 96.6% of the total gangue.

Experiment 5 shows less of the coarse gangue material floated than any others. This concentrate was made on machine No. 3 which allowed the coarse gangue material to settle to a certain degree.

Experiment 6 shows a low percentage of material on the coarse mesh due to the fact that the original flotation feed shows a high percentage of fine material.

NAME AND ADDRESS OF COMPANIES FURNISHING OILS FOR FLOTATION

Wood Oils and Mixtures

Cleveland Cliffs Iron Co., Cleveland Ohio. Sales Office.
United Naval Stores, 130 Pearl St., New York City.
General Naval Stores, 175 Front St., New York City.
Pensacola Tar and Turpentine Co., Gull Point, Fla.
Forest Products Chemical Co., Memphis, Tenn.
Florida Wood Products Co., Jacksonville, Fla.
Georgia Pine Turpentine Co., 185 Perry St., New York City.
Yaryan Rosin and Turpentine Co., Brunswick, Ga.
Southern States Turpentine Co., Cleveland, O.
Central Distilling Co., Helena, Ark.
Hussay and O'Connel, Savannah, Ga.
Spiritine Chemical Co., Wilmington, N. C.
National Wood Products Co., Wilmington, N. C.
Oregon Wood Distilling Co., Portland, Ore.
Summit Naval Stores Co., Summit, Ga.

Coal Tars and Derivatives

American Tar Products Co., South La Salle St., Chicago, Ill.
F. S. Lewis Mfg. Co., Chicago, Ill.
Barret Co., Battery Place, N. Y. City.
American Creosoting Co., New Orleans, La.
American Coal Refining Co., Denver, Colo.
Republic Creosoting Co., Minneapolis, Minn.

Petroleum Products

Pierce Oil Corporation, St. Louis, Mo.
Standard Oil Co., Richmond, Cal.
The Texas Co., Houston, Texas.
Continental Oil Co., Salt Lake City, Utah.
Geo. P. Jones & Co., St. Louis, Mo.
Utah Oil Refining Co., Salt Lake City, Utah.
Star Lubricating Co., Salt Lake City, Utah.
National Refining Co., Cleveland, O.
Keystone Lubricating Co., Philadelphia, Pa.
Gulf Pipe Line Co., Tulsa, Okla.
Chelsal Refining Co., Chelsal, Okla.
Union Oil Co., San Francisco, Cal.

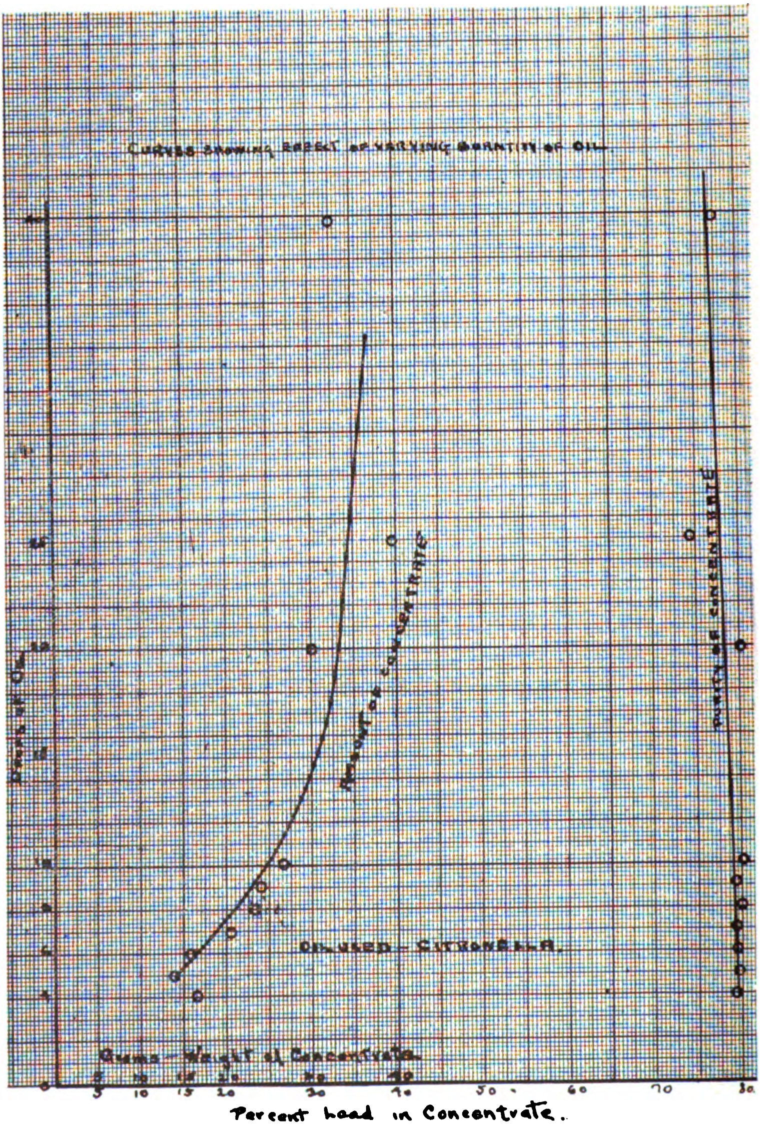
Essential Oils

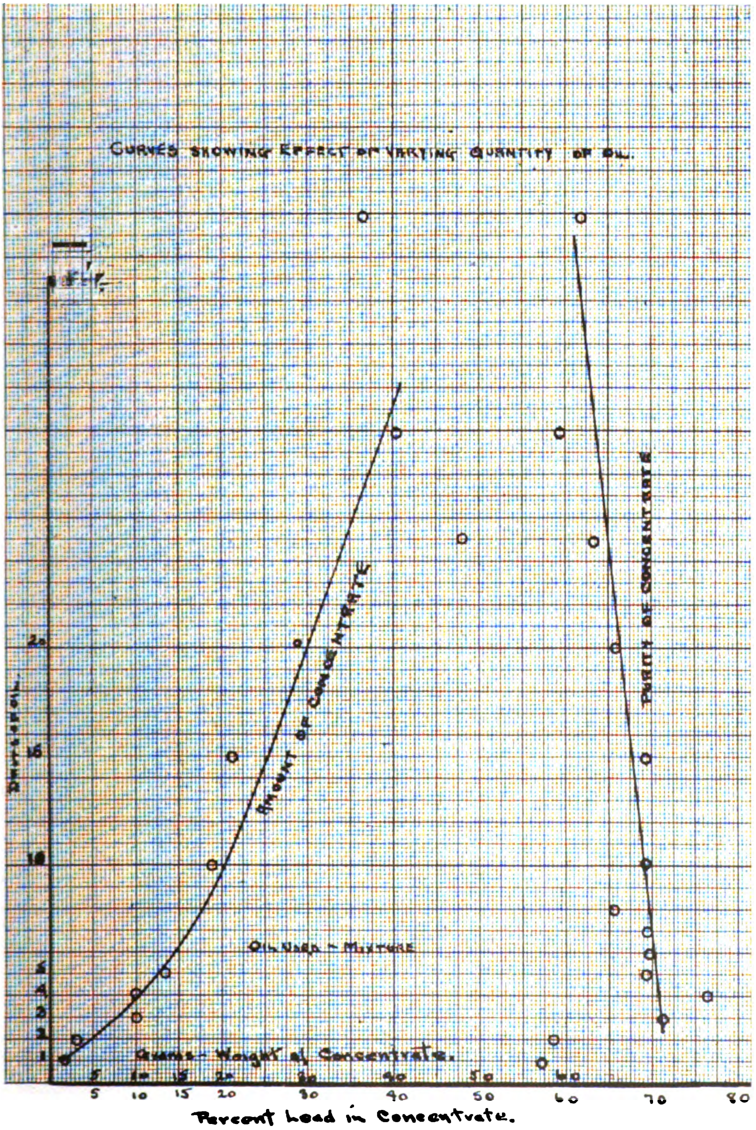
Edward Hills & Co., 64 Wall St., N. Y. City.
McKesson & Robbins, 91 Fulton St., N. Y. City.
Atkins Kroll & Co., San Francisco, Cal.

Arnhold, Karberg Co., of China, 21 State St., N. Y. City.
Antoine Chivis Co., 18 Platt St., N. Y. City.
Synflenun Scientific Laboratories, Monticello, N. Y.
A. M. Todd, Kalamazoo, Mich.

Fixed Oils

Southern Cottonseed Oil Co., Memphis, Tenn.
Emery Mfg. Co., Bradford, Pa.
Emlenton Refining Co., Emlenton, Pa.
Crystal Oil Works, Oil City, Pa.
Empire Oil Works, Oil City, Pa.
Waverlt Oil Works, 54th St., Pittsburg, Pa.
Peter van Schaadt Co., Chicago, Ill.
Mohawk Refining Co., Cleveland, O.
Corn Products Co., New York City.
Consolidated Oil Co., Cleveland, O.


Curves showing effect of varying quantity of oil.
Drops of Oil
Amount of Concentrate
Purity of Concentrate
Oil used – Citronella.
Grams – Weight of Concentrate.
5
10
15
20
30
40
0
5
10
15
20
30
40
50
60
70
80
Percent Lead in Concentrate.


CURVES SHOWING EFFECT OF VARYING QUANTITY OF OIL.
AMOUNT OF CONCENTRATE
PURITY OF CONCENTRATE
DROPS OF OIL
Oil Used — Mixture
Grams — Weight of Concentrate.
1
2
3
4
5
10
15
20
5
10
15
20
30
40
50
60
5
10
15
20
30
40
50
60
70
80
Percent Lead in Concentrate.

AN ATTEMPT TO FLOAT COPPER CARBONATE

M. H. Thornberry

At the present time copper carbonate is being concentrated by oil flotation after first coating the carbonate with a sulphide film. The following experiments were made in an effort to float the copper carbonate direct without first giving it a sulphide filming.

The charge for each experiment consisted of 500 grams of the ore in 3200cc. of water. After the charge of ore and water was put into the machine, it was agitated for a few minutes, then one-half cubic centimeter of oil from crude water-gas tar was added, and the agitation continued for five minutes, after which a small amount of frothing agent was added. The oil acted as a collector for the sulphide, forming a thin film on the surface of the water. The frothing agent floated the carbonate and at the same time retained the sulphide in the froth so that it was possible to remove both the sulphide and the carbonate together. After the charge had run 20 minutes, more oil was added, and if it was needed to maintain the froth, more frothing agent was also added. The agitation was continued for 25 minutes longer, or until no more ore floated. The concentrate was then recleaned, weighed and assayed.

The frothing agents used in this work consisted of Naptha Powder, manufactured by Peet Bro's. and Oleic Acid. Each charge contained 1-2 gram of the powder and from two to three drops of Oleic Acid. Many frothing oils were tried out but not one was found that would float the carbonate.

These tests were all made in machine No. 1 in the flotation laboratory.

The ore, oil, frothing agent and operation were the same in each case.

ORE. Copper ore; mixture of the sulphide and carbonate, assaying 2.95% copper.

OIL Kind, oil from crude water gas tar; amount used, 0.7cc. pounds per ton 1.7.

FROTHING AGENT. Kind, soap—Naptha Powder; Oleic Acid; amount used, 1-2 gram of the powder and from two to three drops Oleic Acid; pounds per ton 2.

OPERATING DATA. Time, 45 minutes; amount of water 3200cc.; amount of ore 500 gram; speed of machine 1700 r.p.m.

Table No. 1 Tap Water

Test No.	Concentrate		Tailing	Extraction %
	Weight	Copper %	Copper %	
1	28	14.76	1.87	25
2	34	12.32	1.67	28
3	40	15.36	1.26	47
4	31	16.21	1.41	32
5	43	17.86	1.06	52
6	42	18.08	0.89	52

Table No. 2, Distilled Water

1	30	14.89	1.38	38
2	38	22.37	0.76	57
3	33	25.36	0.75	57
4	31	27.74	0.71	58
5	32	28.45	0.65	62
6	31	30.47	0.62	67

Table No. 3, Rain Water

1	26	23.14	1.21	41
2	41	19.87	0.87	55
3	42	20.16	0.91	57
4	39	21.16	0.77	56
5	38	22.26	0.69	58
6	35	28.46	0.63	67

In the foregoing work each concentrate was given a microscopic examination. This examination showed that both the sulphide and carbonate floated. In the preparation of this article for publication it was suggested that this was not sufficient proof to be convincing to one who had not seen the float. Therefore, the original ore was assayed for total and oxidized copper. This assay shows that the ore treated consisted of 2.95% total copper of which 2.34% was oxidized copper. The concentrate and tailing of tests number four, five and six in table No. 2 had been saved and these were assayed for oxidized and total copper with the following results:

Concentrate		Tailing	
Oxidized copper. %	Total copper %	Oxidized copper. %	Total copper %
15.16	27.74	0.64	0.71
14.92	28.45	0.58	0.65
17.26	30.47	0.52	0.62

Four additional tests were made on this ore using distilled water. The oil, frothing agent, and operating data were the same as recorded in the previous tables. The results of these tests are shown below.

Test No.		Concentrate		Tailing		Extraction
	Weight	Oxidized Copper %	Total Copper %	Oxidized Copper %	Total Copper %	%
4.	50	9.87	19.46	0.59	0.68	66
1.	41	10.37	20.15	0.67	0.71	56
2.	43	11.72	22.05	0.71	0.87	64
3.	57	8.66	16.81	0.65	0.86	65

Tests are now being made to determine whether the carbonate can be floated in tap water. So far no definite results have been obtained but some very interesting things have been noted. First, if any reagent which contains a sulphate, or the sulphate radical, be added to a charge of distilled water and ore the carbonate will not float. Second, if any reagent which contains a chloride, or the chloride radical, be added to a charge of distilled water and ore the carbonate will not float, but the addition of a small amount of soda will counteract the effect of the chloride and the carbonate will float.

The following conclusions are drawn:

(1) With rain or distilled water this process can be used to an advantage.

(2) Water containing sulphates will prevent the carbonates from floating.

(3) Water containing chlorides will prevent the carbonates from floating, but this difficulty can be overcome by the addition of sodium carbonate.

MISSOURI SCHOOL OF MINES BULLETINS
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Volume Three Number Three

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

BULLETIN

FEBRUARY, 1917

TECHNICAL SERIES

A PRELIMINARY REPORT ON BLENDED PORTLAND CEMENT

ROLLA, MO.
1917

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SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

◆

A PRELIMINARY REPORT ON BLENDED PORTLAND CEMENT

BY

EDGAR S. McCANDLISS, C. E.,

Assistant Professor of Civil Engineering

◆

ROLLA, MO.
1917

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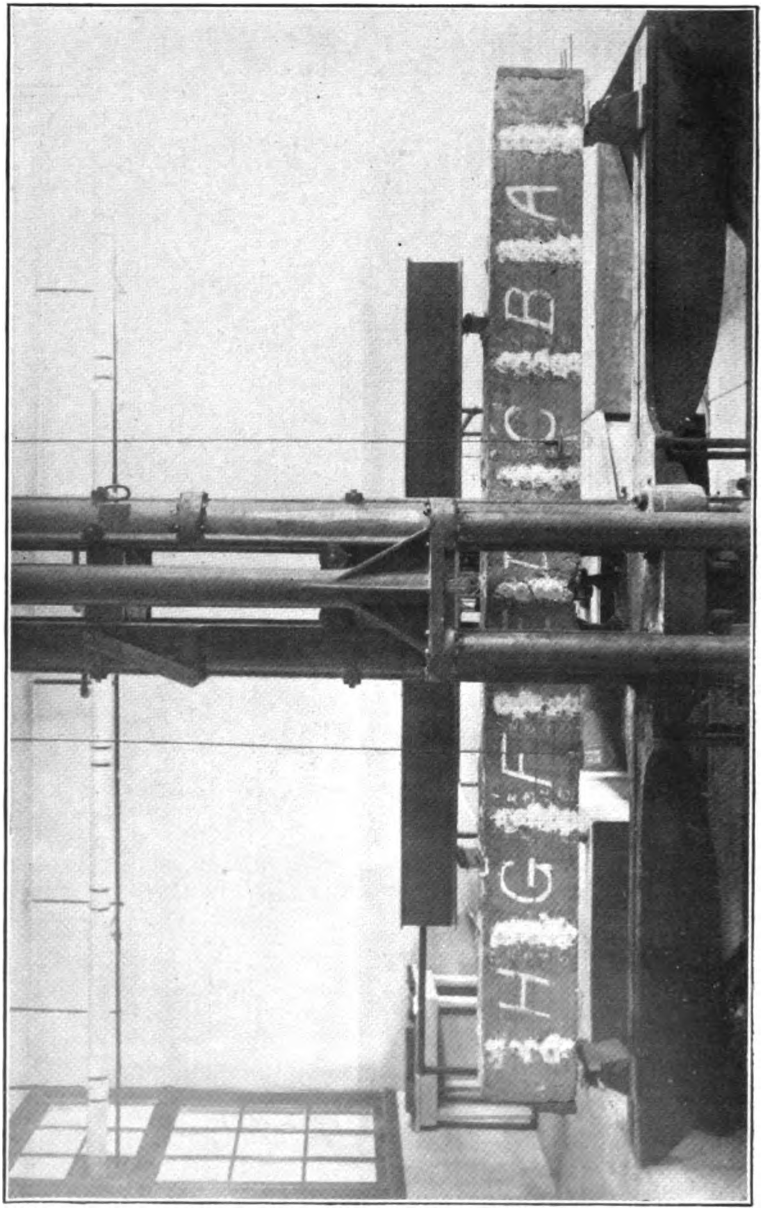

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BULLETIN

OF THE

School of Mines and Metallurgy

UNIVERSITY OF MISSOURI

TECHNICAL SERIES

Vol. III FEBRUARY, 1917 No. 3

INTRODUCTION

In the fall of 1913 in conjunction with the regular classwork in the cement testing laboratory of the Missouri School of Mines, the author undertook the study of the behavior of sand-blended cements. The results obtained were somewhat surprising, but owing to the limited facilities for carrying on the work, extended investigations were not made at that time. But in 1915 with the installation of the present well equipped laboratory for the testing of materials, it became feasible to carry out experimentation along more extensive lines. One of the problems to receive attention was the continued study of sand-blended cements.

The questions taken up were:

1. Can Portland Cement be blended with sand to produce a sand-blended cement having the same general physical properties as Portland Cement?
2. What amount of sand can be blended with Portland Cement without materially impairing the strength of the blended mixture?
3. In grinding cement clinker, does introducing sand with the clinker in a tube or ball mill facilitate fine grinding?

About three thousand test specimens for tension and compression have been prepared. In order that differences due to personal equation might not affect the results all of these specimens were prepared by the author. It was planned to have the tests extend over a period of two years. The work was started in the fall of 1915 and will be completed in the summer of 1918. This Bulletin gives the tests made on question 1 during the first year. The results of tests on questions 2 and 3 for one year will be completed in October, 1917.

The author takes pleasure in thanking the various cement companies for their co-operation in supplying the cement for these investigations. He is indebted to Mr. H. A. Buehler, Director of the Missouri Bureau of Mines and Geology, for his assistance and advice, and to Messrs. B. L. Ashdown, E. C. Burkhart, C. E. Bardsley, and T. C. Gerber, students in civil engineering at the Missouri School of Mines, for their cheerful assistance.

CALCAREOUS CEMENTS

The term cement has been applied: To any substance or composition which at one temperature or one degree of moisture is plastic and at another is tenacious; to adhesive mixtures employed to unite objects or parts of objects; to any material, capable of adhering to and uniting into a coherent mass, fragments of a substance not in itself adhesive; to any substance which by hardening causes objects between which it is applied to adhere firmly; to a tenacious infusible substance; to an adhesive or viscous substance; in general to any substance capable of uniting or tending to unite particles of matter into a compact whole. Lutes, glues, solders, gums, putty, mucilage, plasters, limes, hydraulic cements, and similar substances are all comprehended in this definition. Such a definition embraces a large variety of substances which differ one from another in composition, behavior, and importance, and have but few characteristics in common. Because of this, the term cement has become more or less generally restricted to the designation of that group of adhesives which is employed in the construction of engineering works. Cements of this kind bear a chemical relationship to each other, consisting as they do of mixtures which contain compounds of lime as their principal ingredient, in consequence whereof they are termed calcareous cements. Of these the most important by far is Portland Cement.

Portland Cement is a composition, the principal constituents of which are compounds of lime and clay. The abundance of these substances in nature, and the usefulness and cheapness of the cement combine to make it a universal material of construction.

The manufacture of Portland Cement is a highly specialized art, but in general it may be briefly outlined as follows: The clay and the lime are artificially mixed in predetermined proportions depending upon the purity of the materials. This mixture is reduced by grinding to a fine powder and the product roasted at a high temperature. This roasting causes the powder to undergo chemical and physical changes and the result is a semi-vitrified clinker. This clinker is commonly adjudged to be inert, or devoid of the properties of cements, but when reduced to an extremely fine powder the finest particles possess the property of cements. Hence, in general, Portland Cement may be defined as the material obtained by finely pulverizing the clinker produced by calcining to incipient vitrifaction an intimate artificial admixture of properly proportioned argillaceous and calcareous substances.

Why it is that the particles of the cement clinker are inert when of appreciable size and those of inappreciable size are active, has never been conclusively determined. Nor has the exact size or upper limits in size of the active particles been ascertained. It has, however, been conclusively demonstrated that any particle which will not pass through a standard No. 200 screen has no cementing properties and also that such particles as do pass through this screen are not necessarily active, but that a considerable percentage of it is practically inert. The present standard specifications for fineness of Portland Cement permit of 22% by weight to be retained on a standard No. 200 sieve. Hence it follows that commercial Portland Cement is a material composed of both active and inert particles, the latter being inactive on account of their physical coarseness and their amount being a large percentage of the cement. The desirability of continuing the grinding to reduce this percentage of inactive clinker has been a much discussed problem. But since the apparent increase in strength in the cement is not in proportion to the increased cost of manufacture, and also since the physical behavior of the cement so changes with continued grinding that it sets more rapidly, it appears that the economic limit of grinding cement clinker has been reached. On the other hand, the very fact that these inert particles are present in the cement in large amounts and that they are in reality dormant cement, needing only the energy to break them down to bring out their latent cementing qualities, suggests the presence of a considerable economic waste. If it is necessary to maintain the present graduation in the size of the particles in order to control the behavior of the cement, it is quite possible that some other substance less expensive than cement clinker can be used for the large size particles. In other words, if it is necessary to have these inert particles present in the cement, there are other inert substances in nature, which might be used as a substitute for the inert clinker particles in case the substitution could be made, thus permitting the further reduction of the clinker into active cement. It is assumed that such a substitution can be accomplished and it is here proposed to study the effect of such a procedure.

The product obtained by mixing Portland Cement with some other finer pulverized substance in a dry condition before being used in mortar or concrete, is commonly termed "blended cement." The substance which is mixed with the Portland Cement is designated the "blending material, or the blend." This latter may be either entirely inactive as a cement or may possess cementing qualities.

The blending of Portland Cement is no innovation as the practice probably made its first appearance in the early nineties. But, owing to the rapid development of the Portland Cement industry with the accompanying reduction in the cost of the product, the practice has been largely discontinued. These cements were manufactured in general by merely mixing the ingredients, Portland Cement and the blend, in a ball or tube mill, no especial effort being made to continue the grinding of the cement. This product was marketed under various trade names such as "silica cement," "sand cement," "tufa cement," etc., the name depending largely upon the nature of the blending material used. While these cements have no importance in present construction as a general proposition, still the economic advantages derived from such methods have not passed into absolute obscurity. Several noteworthy instances might be cited where large constructions have been carried on in which blended cement has been used with satisfaction, whereby considerable economies have been effected. Among the more recent and important of these are the works of the U. S. Reclamation Service and the Los Angeles Aqueduct Commission. In these undertakings the justification for using blended cements has been based largely upon the excessive transportation charges due to the remoteness of the projects from industrial centers. While this condition existed, it is unfortunate that thereby the inference has been given that otherwise blended cements would not have been used, for it is quite possible that in creating this impression an injustice has been done to a worthy practice. The theory has also been advanced that only materials containing active or colloidal silica are suitable for blending Portland Cement. This, of course, excludes quartz sand, and here again it is possible that an erroneous notion is conveyed, for, although it is not proposed to discuss the relative merits of quartz sand as a blend, yet an endeavor will be made to show that it can be used satisfactorily for this purpose.

PURPOSE

The purpose of this investigation was to study the physical behavior of blended cement of which the blending material was quartz sand. It was proposed to manufacture the blended cements in such a way. as to approach as near as possible the same range in gradation in size of the particles, as occurs in the original Portland Cement. In other words, it was proposed to remove from the Portland Cement a large portion of the inert particles by screening, and for these inert particles to substitute other inert particles of about the same in size. No accurate means were devised for determining the precise amount of the particles removed from the Portland Cement, and therefore several combinations were used which it was thought would give sufficient range to obtain a satisfactory comparison. The end desired was to ascertain whether it is essential in Portland Cement, in order to maintain its present physical characteristics, to have unpulverized clinker for the coarser particles or whether a fine sand would serve the purpose equally well, sand being used because of its having no cementing tendencies and its being abundant in nature.

SCOPE OF TESTS

The data included in this Bulletin was obtained from testing three commercial Portland Cements and twelve blended cements. For convenience, the tests are grouped in three series, namely, A, B, and C.

Series A comprises the tests of Atlas Portland Cement and four blended cements of this brand. These blended cements are composed (1) of such a portion of the Portland Cement as easily passes No. 200 sieve, and (2) quartz sand, all of which has passed a No. 65 sieve, and about seventeen per cent of which has passed a standard No. 200 sieve. These blended cements, for convenience of identification, are designated A_{10}, A_{20}, A_{30} and A_{40}. the numerals indicating the percentage of weight of sand present in the blended cement.

Series B comprises the tests of Lehigh Portland Cement and four blended cements of this brand. The composition of these blended cements is similar to that of series A and they are designated similarly as B_{10}, B_{20}, B_{30}, and B_{40}.

Series C comprises the tests of Red Ring Portland Cement and four blended cements of this brand. The composition of these blended cements is as before, and they are designated as C_{10}, C_{20}, C_{30}, C_{40}.

Thus it is seen that the three series are identical except the Portland Cements used are different. Chemical analyses were made of each of the materials and the usual physical determinations were made of each of the commercial and blended cements. In addition test specimens for neat and mortar tension and compression were made to cover a two years' period of testing. The results of these tests, but only for the period of one year, are given complete in this Bulletin.

MATERIALS

In selecting the materials for use, an effort was made to choose such brands of Portland Cement as would give some range in the character of the component raw ingredients. The basic composition of the Atlas Portland Cement is Mississippian limestone and Pennsylvanian shale; that of the Lehigh Portland is hard Mitchell (Mississippian) limestone and shale; and of the Red Ring Portland, Missippian limestone, Pennsylvanian shale, together with Loess clay. There is no especial difference in the methods used in manufacturing these cements.

The blending material used was a natural quartz sand from Ottawa, Illinois. It was supplied by the Ottawa Silica Company and is marketed under the trade name of "Banding Sand." This sand is quite fine but well graded and with but slight sifting, as has been noted, was found to conform closely in gradation to that of the coarser particles in the Portland Cement, and was therefore a suitable substitute for them in making the blended cement.

For mortar specimens, standard Ottawa sand was used.

Each of these materials was received at the laboratory in good condition and stored in suitable containers. The respective Portland Cements were each passed through a No. 20 sieve before storing to insure uniformity throughout the samples.

PROCEDURE

The physical tests made were as follows: (a) Neat tension, (b) mortar tension (c) neat compression, (d) mortar compression, (e) normal consistency, (f) time of setting, (g) constancy of volume (normal and accelerated tests), (h) fineness and sieve analysis and (i) specific gravity. The methods for testing cement recommended by the American

Society of Civil Engineers (See Transactions Vol. 75) were followed but with the following exceptions: A sieve analysis was made of each of the cements. The percentage of water used in making mortar specimens was increased one per cent above the recommended values. Sufficient specimens for neat and mortar tension and compression were made to permit of making tests at intervals up to and including two years, the average of three breaks constituting a test. As has been stated above, the two-year tests have not been made, in consequence the results are complete over only a period of one year.

Compressive test specimens were cylinders two inches in diameter and two inches high. They were made in wooden moulds which had been especially prepared for the purpose. These moulds were twelve inches long, four inches wide, and two inches high, and were made in two sections. The sections were held together with dowels and bolts and were provided with three two-inch holes symmetrically placed on the axis of the block. Poplar wood was used, and the moulds were finished and painted and, as an added precaution against absorption of the water from the specimens, the moulds were greased with hard engine oil each time before being used. The moulds were satisfactory, and good specimens were obtained. No tamping device was used, all moulds being filled by hand.

Compression tests were made with two-screw testing machine of the Riehle type, having a capacity of 50,000 pounds. Each specimen upon being removed from the storage tank was calibrated and weighed to ascertain the relative density. The specimens were at once mounted in the machine on a hemispherical bearing plate and imbedded in plaster of Paris. After centering the specimen in the machine, a light initial load was applied. After the plaster had hardened, continuous load was applied, the moving head of the testing machine travelling at a rate of about .06 inch per minute until failure. The load when first crack appeared in the specimen, as well as the ultimate load, was recorded. These loads were reduced to unit stresses for comparison.

Each of the blended cements was put through the same tests as the Portland Cements except that the chemical analyses and specific gravities were computed and not determined experimentally and no determinations for fineness or sieve analysis were made. In preparing the blended cements each test was prepared separately, only enough of the materials being laid out at a time to make three test specimens. The coarse particles were removed from the Portland Cements by screening through a standard No. 200 sieve and those of the banding sand by screening through a No. 65 sieve. Enough of each of these materials was then weighed out to produce 500 or 1,000 grams of blended cement in the proportion desired, 500 grams being used in making the test specimens for tension and 1,000 grams the specimens for compression. The sand and the cement were then mixed by passing the mixture successively through a No. 35 screen six times. The resulting blended cement was uniform in color and had every indication of being well combined. It was noted, however, that the materials separated slightly if the containers were dropped lightly upon the table a few times, a fine rim of sand appearing about the base of the cone of the cement. Therefore extreme care was taken not to disturb the blended cements after they were made until they were formed into test specimens.

RESULTS OF TESTS

The results of the tests for neat and mortar tension and compression are tabulated and appended to this bulletin, but for facilitating the interpretation of these data, curve sheets have been prepared and these follow:

(A) Neat Cement in Tension.

On curve sheet No. 1 are plotted the results obtained from tension tests of Atlas Portland Cement "A" and the blended cements made from the same. (See Table A, Appendix.) It will be noted from the curves here shown that each of these cements meets the requirements for neat cement in tension of the standard specifications of the American Society for Testing Materials (1916), which are 175; 500 and 600 pounds at twenty-four hours, seven days, and twenty-eight days respectively. In each case the maximum strength is attained within the first twelve weeks. Cement A, the Portland Cement, attains the greatest maximum strength. For comparison of relative strengths, Table 1 has been compiled. It is intended to show in this table the relative strengths of the five cements at the various ages of testing, the values one to five being assigned to the various relative strengths in their order of importance, 1 indicating the cement developing maximum strength and 5 indicating the one developing the minimum strength at the same period.

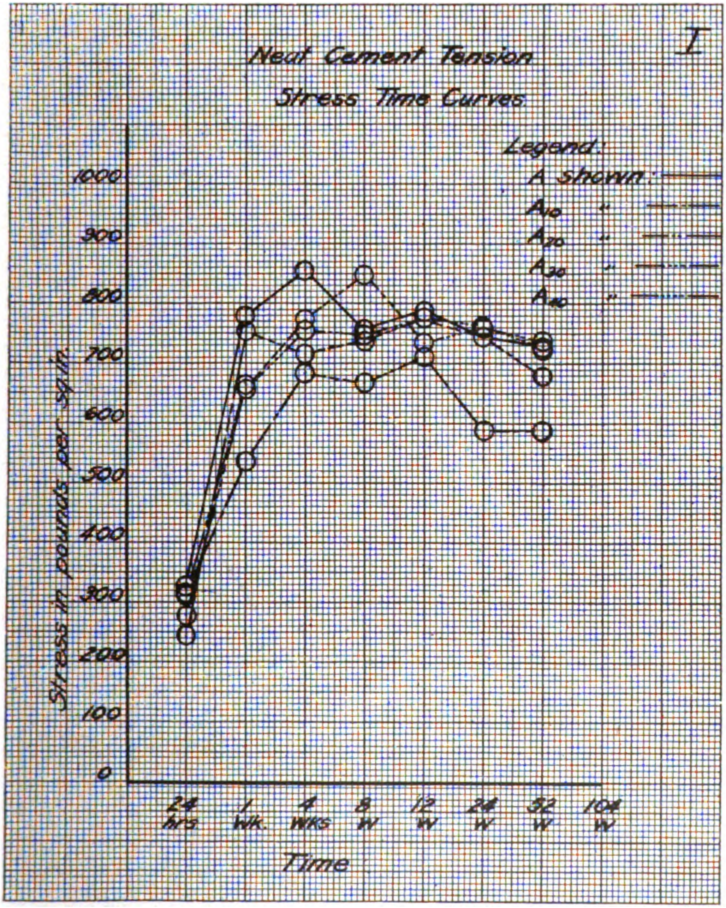

I
Neat Cement Tension
Stress Time Curves
Legend:
A shown:
A10 "
A20 "
A30 "
A40 "
Stress in pounds per sq.in.
1000
900
800
700
600
500
400
300
200
100
0
24 hrs
1 wk.
4 wks
8 w
12 w
24 w
52 w
104 w
Time

TABLE I

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52
A	1	1	1	2	1	3	3
A_{10}	2	5	5	5	5	5	5
A_{20}	5	2	4	4	3	4	4
A_{30}	4	3	2	1	4	2	1
A_{40}	3	4	3	3	2	1	2

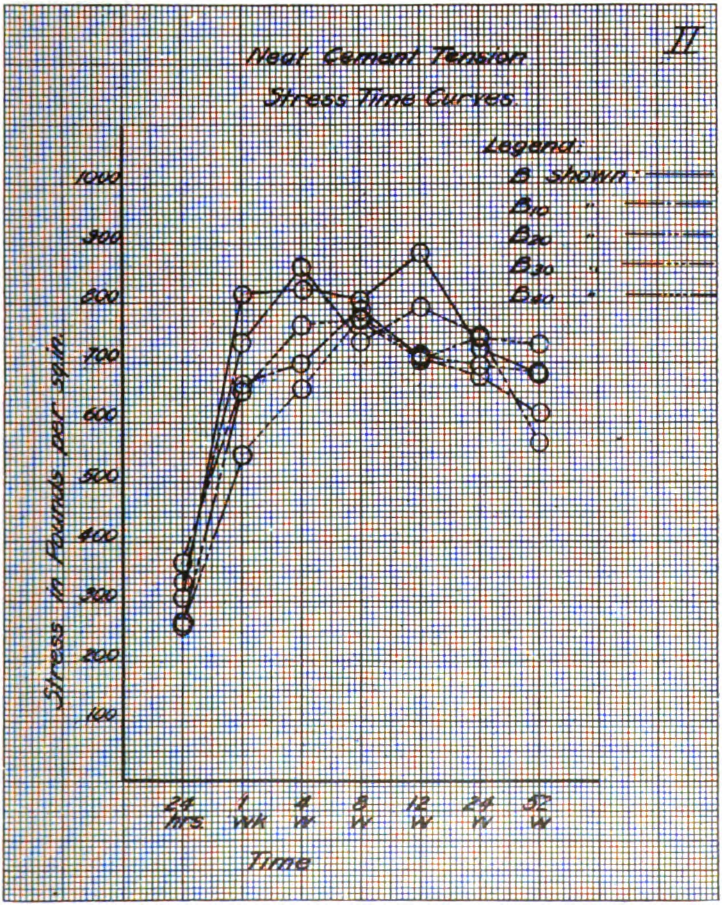
From Table I it is seen that up to and including twelve weeks cement "A" ranges first in point of relative strength. A_{30}, second; A_{40}, third; A_{20}, fourth; and A_{10}, fifth. Upon considering the twenty-four and fifty-two week tests, it is seen that A_{20} and A_{40} rank higher than "A", A_{20} and A_{10} retaining fourth and fifth places respectively. This comparison would seem to indicate that within the scope of these tests the blended cements A_{30} and A_{40} are slightly superior to A_{20} and A_{10} in the tensile strength when used neat. From Curve Sheet I blended cement A_{40} seems to develop the most uniform strength, A_{10} the least. From a consideration of early tests, up to twelve weeks, cement "A" seems to be slightly superior to any of the blended cements, but at greater ages the more highly blended cements have equal or superior qualities.

On Curve Sheet II are plotted the results obtained from tests of Lehigh Portland Cement, "B", and the blended cements from the same. (See Table A, Appendix). Each of these cements meets the requirements of the standard specifications of the American Society for Testing Materials (1916). It is to be noted also that in each case the maximum strength is attained within the first twelve weeks, Cement "B" attaining the greatest maximum strength. Table II is similar to Table I.

TABLE II

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52
B	3	1	2	1	1	3	3
B_{10}	1	3	4	2	4	5	4
B_{20}	2	2	1	5	2	1	5
B_{30}	5	4	3	3	3	2	1
B_{40}	4	5	5	4	5	4	2


II
Neat Cement Tension
Stress Time Curves.
Legend:
B shown:
B_{10} "
B_{20} "
B_{30} "
B_{40} "
1000
900
800
700
600
500
400
300
200
100
Stress in Pounds per sq.in.
24 hrs
1 wk
4 W
8 W
12 W
24 W
52 W
Time

From Table II Cement B seems to rank first in relative strength up to and including twelve weeks. Over this period of time B_{20} ranks second, B_{10}, third; B_{30}, fourth; and B_{40}, fifth. This relationship is not pronounced, however, there being several conflicts. It is quite apparent, however, that after twelve weeks B_{30} and B_{40} increase in relative importance and are equal or superior to B, while B_{10} and B_{20} make a relatively less favorable showing. From Curve Sheet II it is seen that B_{30} develops the most uniform strength throughout the entire period of testing.

On Curve Sheet III are plotted the results obtained from testing Red Ring Portland Cement "C" and blended cements made from the same, in tension. (See Table A, Appendix). Each of these cements meets the requirements of the standard specifications of the American Society for Testing Materials (1916). In each case the maximum strength was attained in twelve weeks. Cement "C" attains the greatest maximum strength. Table III is similar to Table I.

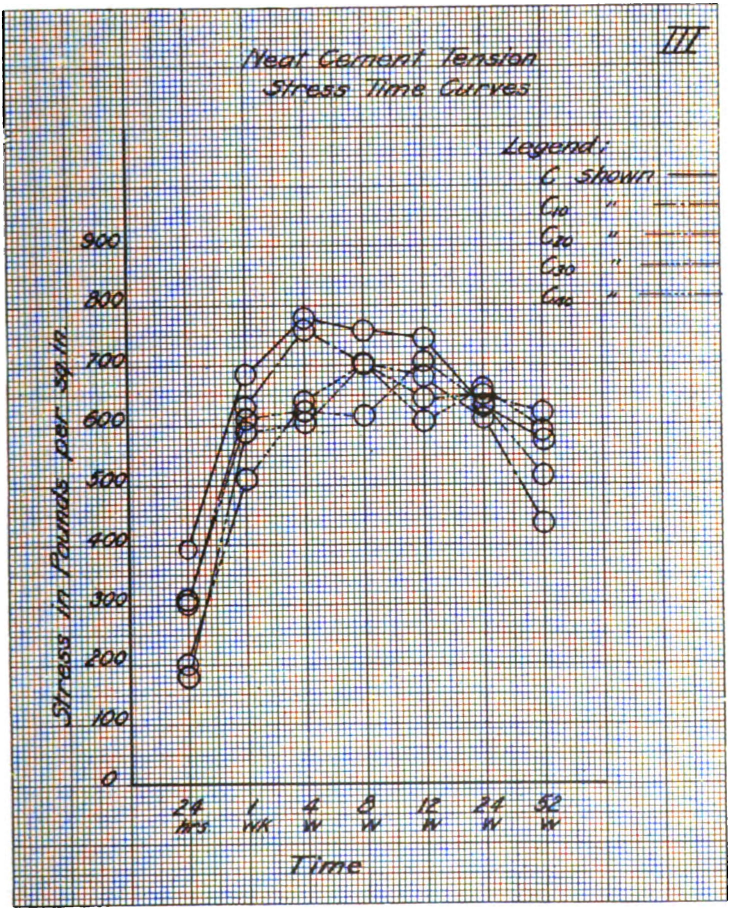
TABLE III

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52
C	1	1	1	1	1	3	3
C_{10}	3	2	2	2	3	5	5
C_{20}	2	3	4	5	2	4	4
C_{30}	5	4	5	4	5	1	2
C_{40}	4	5	3	3	4	2	1

From Table III it is seen that Cement "C" ranks first in relative strength for the first twelve weeks; C_{10}, second; C_{20}, third; C_{40}, fourth; and C_{30}, fifth. This relationship is seen to change, however, as the age increases, C_{30} and C_{40} attaining the greatest relative strengths at the periods of twenty-four and fifty-two weeks, "C" assuming third place; C_{10}, fourth; and C_{20}, fifth. Blended cement C_{40} is seen to develop the most uniform strength throughout the entire range of testing.

On Curve Sheet IV are plotted the results obtained by averaging the corresponding tests plotted on Curve Sheets I, II, and III. (See Table A "Average of averages," Apdendix). From this Curve Sheet it is seen that in each case the requirements of the standard specifications of the American Society for Testing Materials (1916) are satisfied. The


III
Neat Cement Tension
Stress Time Curves
Legend:
C shown
C_{10} "
C_{20} "
C_{30} "
C_{40} "
Stress in Pounds per sq. in.
900
800
700
600
500
400
300
200
100
0
24 hrs
1 wk
4 w
8 w
12 w
24 w
52 w
Time

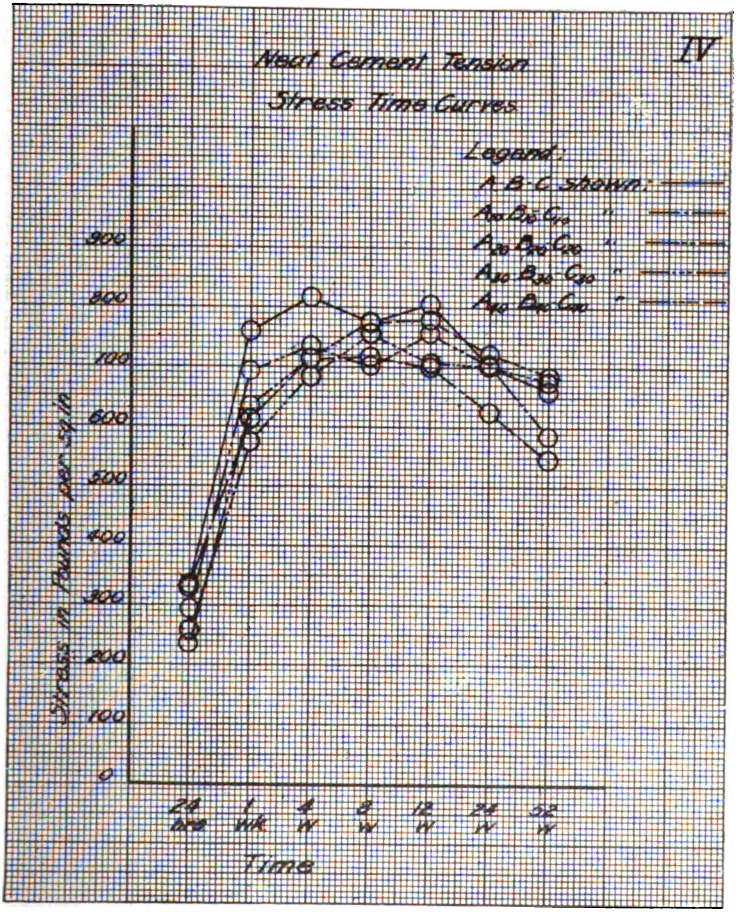
maximum tensile strength is attained in each case in the first twelve weeks. The average of the commercial Portland Cements attains the greatest maximum strength. Table IV is similar to Table I.

TABLE IV

RELATIVE STRENGTHS

Age of test in weeks	(24 hrs.)	1	4	8	12	24	52
A-B-C	1	1	1	1	1	3	3
A_{10} B_{10} C_{10}	2	4	3	4	5	5	5
A_{20} B_{20} C_{20}	3	2	2	5	3	4	4
A_{30} B_{30} C_{30}	5	3	3	2	2	1	1
A_{40} B_{40} C_{40}	4	5	5	3	4	2	2

From Table IV it is seen that the average A, B, C rank first in relative strengths during the first twelve weeks; A_{20}, B_{20}, C_{20} and A_{30}, B_{30}, C_{30} second and third respectively; A_{10}, B_{10}, C_{10} ranking fourth and A_{40}, B_{40}, C_{40} fifth. With increased ages the relative strengths change, the blended cements A_{30}, B_{30}, C_{30} assuming first rank; A_{40}, B_{40}, C_{40}, second; A, B, C dropping into third place, A_{20}, B_{20}, C_{20}, fourth; and A_{10}, B_{10}, C_{10} fifth. It is noted, however, that these changes in relative strengths are not due to increased strengths in the cements with 30 and 40 per cent of blend, but rather to decreasing strengths in the others. The average of the cements with a blend of 45 per cent develops a strength at the age of about four weeks This strength it retains quite consistently as the age increases during the fifty-two weeks of test. The maximum range in variation during this period is about 70 pounds or about ten per cent of the average strength developed. It is intereting to note that the average variation or range in the strengths at the successive periods of testing is about 120 pounds. From a comparison of Curves A, B, and C from Curve Sheets I, II, III, it is seen that the average variation in strength of these commercial cements is about 108 pounds. From this observation, it would seem that had commercial Portland Cements been tested instead of the blended cements and in all other respects had the results been averaged as has been done on Curve Sheet IV, there would have been developed a variation in the strengths practically as great as shown here. In other words there seems to be but little more variation in the strength shown on Curve Sheet IV than might reasonably be expected from that number of commercial Portland Cements, and that in the matter of neat cement in


IV
Neat Cement Tension
Stress Time Curves
Legend:
A-B-C shown:
A_{10} B_{10} C_{10} "
A_{20} B_{20} C_{20} "
A_{30} B_{30} C_{30} "
A_{40} B_{40} C_{40} "
Stress in Pounds per sq. in.
900
800
700
600
500
400
300
200
100
0
24 hrs
1 wk
4 w
8 w
12 w
24 w
52 w
Time

tension within the scope of this investigation the blended cements compare favorably with commercial Portland Cements.

(B) Cement Mortar in Tension.

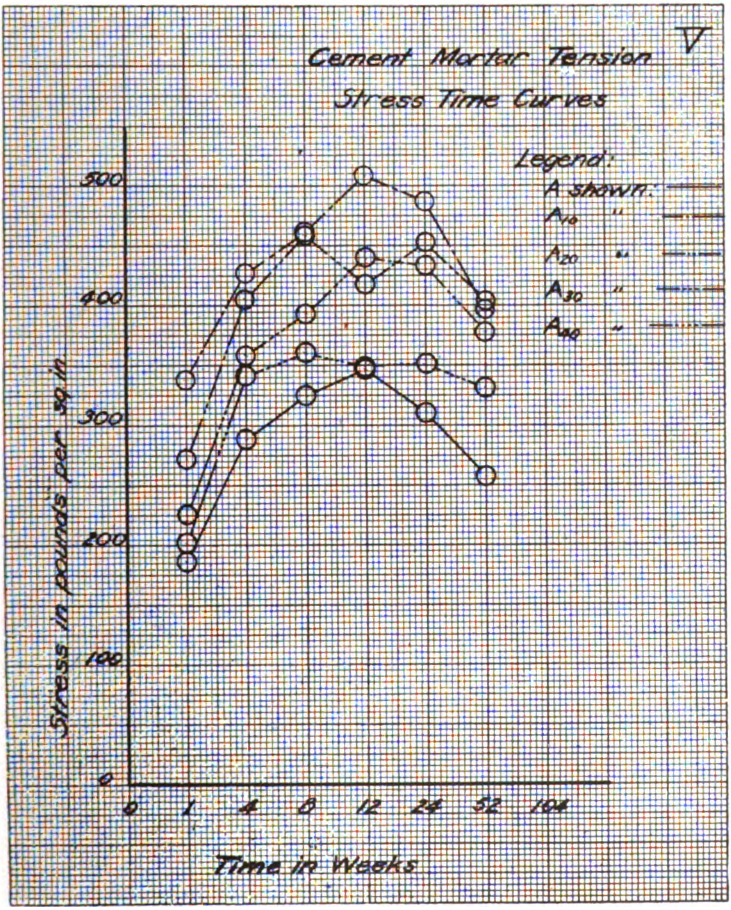
On Curve Sheet V are plotted the results of tests for tension of 1 to 3 mortar specimens of Atlas Portland Cement A and blended cements of the same. (See Table B, Appendix). It will be noted that with the exception of Cement A each of the cements satisfied the requirements of the standard specifications of the American Society for Testing Materials for mortar briquettes in tension, which for 1916 are 200 and 275 pounds per square inch at the ages of seven and twenty-eight days respectively. The specifications for 1917 require 300 pounds per square inch to be developed at the age of twenty-eight days. In each case the maximum strength is attained in the first twelve weeks. Cement A attains the least maximum strength. Cement A_{40} attained a strength of about 350 pounds at four weeks and maintained this strength throughout the remainder of the period. The maximum variation after the first four weeks was about 300 pounds. For the comparison of relative strengths Table V has been prepared. It is similar to Table I.

TABLE V

RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52
A	5	5	5	5	5	5
A_{10}	1	1	1	1	1	2
A_{20}	2	2	2	3	2	1
A_{30}	3	3	3	2	3	3
A_{40}	4	4	4	4	4	4

From Table V it is seen that in relative strength A_{10} ranks first; A_{20}, third; A_{40}, fourth, while the commercial Portland Cement "A" ranks last throughout the entire period of testing.


V
Cement Mortar Tension
Stress Time Curves
Legend:
A shown:
A_{10} "
A_{20} "
A_{30} "
A_{40} "
500
400
300
200
100
0
Stress in pounds per sq. in.
0
1
4
8
12
24
52
104
Time in Weeks

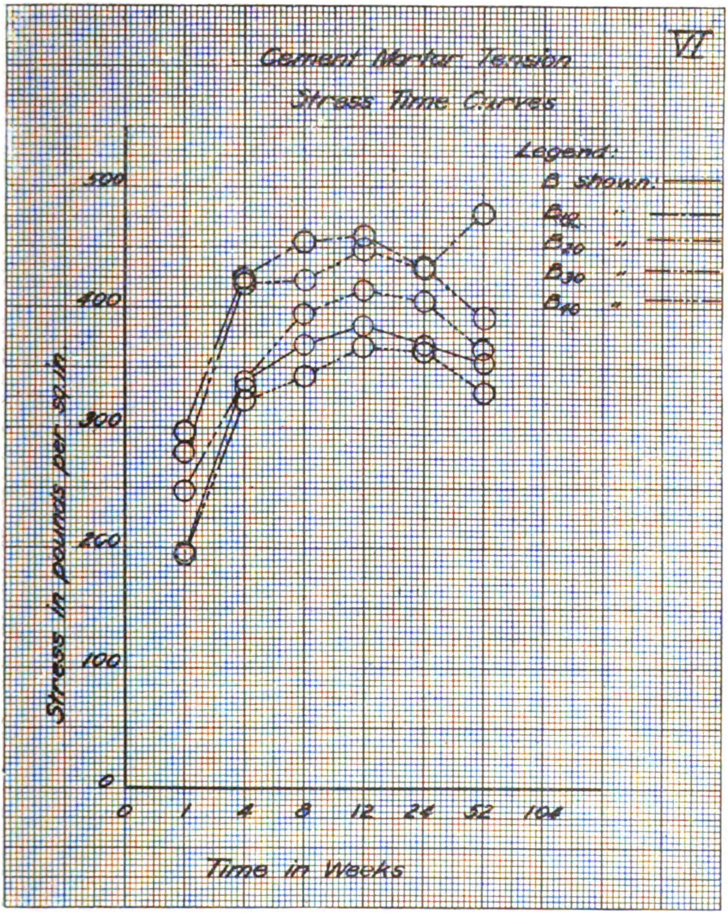
On Curve Sheet VI are plotted the results of tests for tension of 1 to 3 mortar specimens of Lehigh Portland Cement "B", and blended cements of the same. (See Table B, Appendix). It will be noted that each of these cements meets the requirements of the standard specifications of the American Society for Testing Materials (1916 or 1917), for mortar briquettes in tension. Cements B and B_{40} are considered as conforming with the 1917 specifications at an age of one week, with strengths of 197 and 194 pounds per square inch, respectively, in view of their showing at the age of four weeks. Maximum strengths are attained within the first twelve weeks except in the case of B_{10} which shows a maximum strength at fifty-two weeks. Table VI is similar to Table I.

TABLE VI

RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52
B	4	4	4	4	4	4
B_{10}	1	1	1	1	1	1
B_{20}	2	2	2	2	2	2
B_{30}	3	3	3	3	3	3
B_{40}	5	5	5	5	5	5

By reference to Table VI it is seen that B_{10} easily ranks first in relative strength throughout the entire period of tension; B_{20}, second; B_{30}, third; "B", fourth; and B_{40}, fifth.


VI
Cement Mortar Tension
Stress Time Curves
Legend:
B shown:
B10 "
B20 "
B30 "
B40 "
500
400
300
200
100
0
Stress in pounds per sq. in.
0
1
4
8
12
24
52
104
Time in Weeks

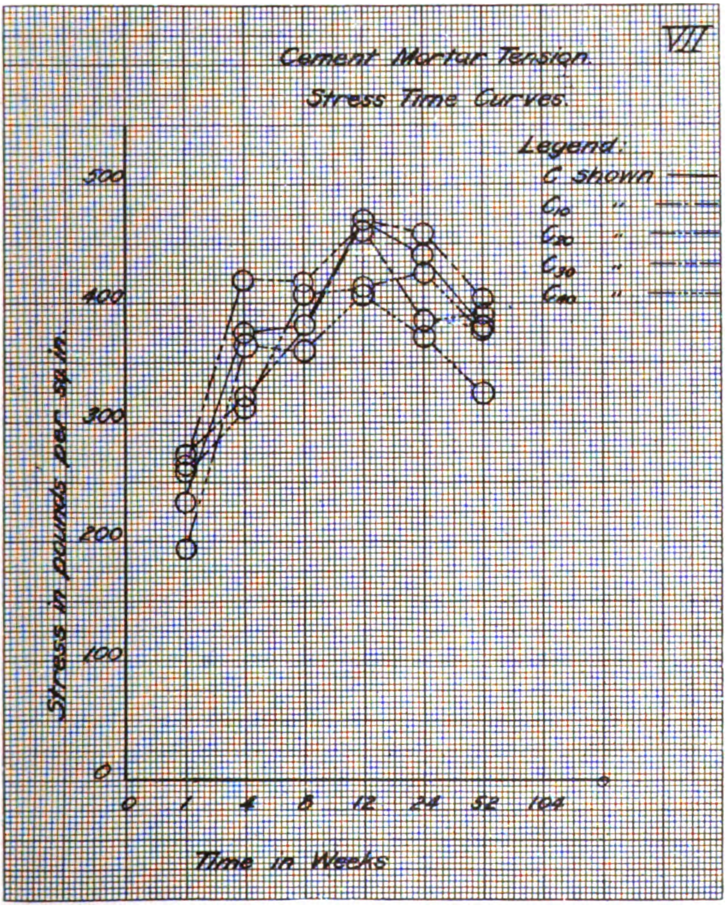
On Curve Sheet VII are plotted the results of the tests for tension of 1 to 3 mortar specimens of Red Ring Portland Cement "C" and blended cements of the same. (See Table B, Appendix). These results seem to be less uniform than those shown on the two previous curve sheets. It will be noted, however, that each of these cements satisfactorily meets the requirements of the standard specifications of the American Society for Testing Materials of mortar briquettes in tension (1916). In each case the maximum strength is attained within the first twelve-week period. Table VII is similar to Table V.

TABLE VII

RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52
C	4	2	3	1	2	3
C_{10}	1	4	3	1	1	1
C_{20}	2	1	1	3	4	2
C_{30}	3	5	2	4	3	4
C_{40}	5	3	5	5	5	5

From Table VII, while it is more difficult to fix relative compression strength than in some of the previous cases, it is apparent that C_{40} should be classified last or fifth in strength; C_{30} should probably receive fourth place; of the remainder, the classification is more difficult and less well defined, but the classification suggested places C_{10} first, C_{20} second, and C third. It will be noted that this classification corresponds to the relative strengths developed at 1, 12, and 52 weeks, respectively.


VII
Cement Mortar Tension.
Stress Time Curves.
Legend:
C shown
C_{10} "
C_{20} "
C_{30} "
C_{40} "
Stress in pounds per sq. in.
500
400
300
200
100
0
0
1
4
8
12
24
52
104
Time in Weeks

The values plotted on Curve Sheet VIII represent the results obtained by averaging corresponding values from those plotted on Curve Sheets V, VI, and VII. (See Table B, "Average of averages," Appendix). The results obtained from averaging A, B, and C, the three specimens of commercial cement mortar in tension, should represent approximately the behavior of an average commercial Portland Cement. This curve sheet corresponds with Curve Sheet IV except that the latter is for neat cement in tension. It will be noted here that each of these cements satisfies the requirements of the standard specifications of the American Society for Testing Materials (1916) for cement mortar in tension. Each of the cements attain maximum strength during the first twelve weeks. The differences in strength at any age is not radical, 100 pounds being an approximate average range in strength. For ascertaining relative strengths Table VIII is shown which is similar to Table I.

TABLE VIII

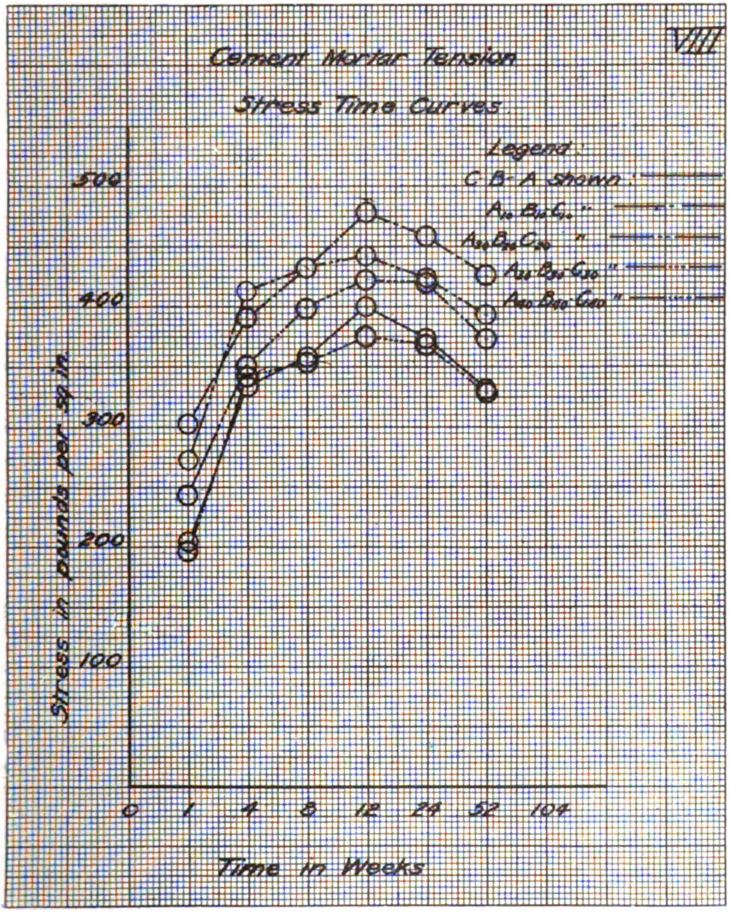
RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52
A B C	4	5	4	4	4	4
A_{10} B_{10} C_{10}	1	2	1	1	1	1
A_{20} B_{20} C_{20}	2	1	1	2	2	2
A_{30} B_{30} C_{30}	3	3	3	3	3	3
A_{40} B_{40} C_{40}	5	4	5	5	5	5

Table VIII gives the following classifications: A_{10}, B_{10}, C_{10} first; A_{20}, B_{20}, C_{20} second; A_{30}, B_{30}, C_{30} third; A, B, C fourth; and A_{40}, B_{40}, C_{40} fifth. by reference to Curve Sheet VIII, it is seen that there is but little difference in strength in A, B, C and A_{40}, B_{40}, C_{40}. In the case of cement mortar in tension, the results of these investigations show that the blended cements are equal or superior to Portland Cement.

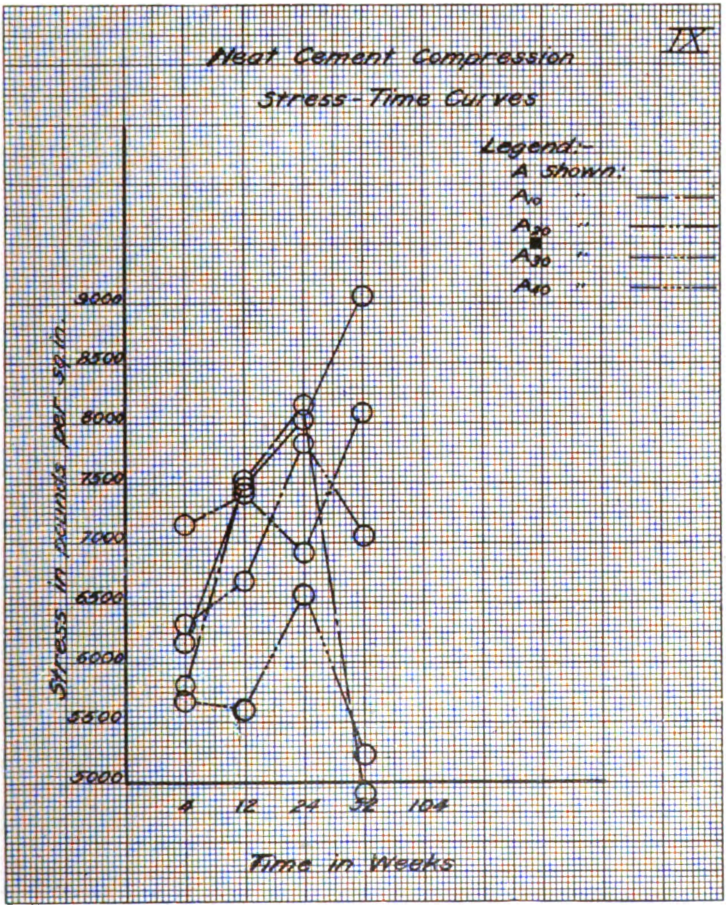
(C) Neat Cement In Compression.

The results obtained from each cement in compression cannot be considered satisfactory in all respects. They are apparently inconsistent and contradictory. Tests of a cement made at different time periods seem to follow no general law. In some cases, maximum strengths occur with


VIII
Cement Mortar Tension
Stress Time Curves
Legend:
C-B-A shown:
A_{10} B_{10} C_{10} "
A_{20} B_{20} C_{20} "
A_{30} B_{30} C_{30} "
A_{40} B_{40} C_{40} "
Stress in pounds per sq. in.
500
400
300
200
100
0
1
4
8
12
24
52
104
Time in Weeks

the oldest tests; in others, at the early test periods. The cause of this eccentricity in results is not apparent. Extreme care was maintained throughout the entire period of experimentation in order to secure uniform conditions, and it is felt that all specimens were treated substantially alike. If it is characteristic of neat cement in compression to show no more uniformity in the results than those here obtained, there seem to be no data available to establish the fact. It is significant, however, that the results obtained from the Portland Cements are no more consistent than those gotten from the blended cements, and in no single instance do the results obtained show uniformity of behavior throughout. The like blended cements of the three commercial Portlands show but slight similarity and the commercial Portlands differ one from the other in behavior. The results obtained are submitted without further apology, but it is hoped that further experimentation will afford a basis for a satisfactory explanation of the behavior of these cements in compression. Attention is called to the fact that this is not a standard test, and in consequence there is no specification to be satisfied, but none of all of these tests, with but a single slight exception, falls below the limit of safety for most large buildings, that is, 5000 pounds per square inch.

On Curve Sheet IX are plotted the results obtained from testing Atlas Portland Cement "A" and blended cements of the same in compression (neat). (See Table "C", Appendix). As has been noted, there seems to be no uniformity in the behavior of the various curves. Cement "A" shows a substantial increase in strength throughout the duration of the test, and it would appear that the maximum strength which this cement may attain has not been reached. It is probable, though, that the strength which is attained at 52 weeks will not be greatly increased at later periods. Cement A_{10} follows closely that of "A" within the first 24 weeks, there being but slight preference between them. The unusual drop experienced in the 52-week test of A_{10} is one of the surprises encountered. A review of the results of this 52-week test shows that they have sufficient uniformity to warrant their acceptance and renders unnecessary the breaking of the two-year specimens at this time for check tests. The two-year tests, however, will be matched with interest. Cement A_{20} develops no unusual characteristics, the average results throughout the entire period being fairly consistent. The same may be observed of A_{30}. The most unusual development in the tests of A_{40} seems to be the relatively low strength at 52 weeks. No effort is made at this


IX
Neat Cement Compression
Stress-Time Curves
Legend:-
A shown:
A10 "
A20 "
A30 "
A40 "
Stress in pounds per sq. in.
9000
8500
8000
7500
7000
6500
6000
5500
5000
4
12
24
52
104
Time in Weeks

time to account for this drop in strength. It is hoped that the strength at two years will tend to offset this apparent inconsistency. Table IX is similar to the previous tables, used in comparing relative strength at the various time-intervals, numerals 1 - 5 being assigned to the highest and lowest strengths.

TABLE IX

RELATIVE STRENGTHS

Age of test in weeks	4	12	24	52
A	3	2	2	1
A_{10}	4	1	1	5
A_{20}	1	3	4	2
A_{30}	2	4	3	3
A_{40}	5	5	5	4

Exclusive of the 52-week tests, A_{10} has developed the highest average relative strength; A, second; A_{20}, third; A_{30}, fourth; and A_{40}, fifth, although the first four classifications are not consistently defined. Inclusive of the 52-week tests the relative classification gives Cement "A" first rank; A_{20}, second; A_{10}, third; A_{30}, fourth; and A_{40}, fifth.

Curve Sheet X is similar to Curve Sheet IX, except that the results plotted are for Lehigh Portland Cement "B" and blended cements of the same. (See Table C, Appendix). Here again many inconsistencies seem to exist; the tests of Cement "B" show marked variation in strength, it having attained a maximum strength at twelve weeks with an accompanying falling off of about 2500 pounds at the 24-week test-period. B_{10} develops an unusual strength at twelve weeks, but this is not maintained at the later periods of testing. This cement develops a very satisfactory average strength throughout the period of testing. B_{20} develops very satisfactory strengths up to and including 24 weeks; but the 52-week test is unusually low. This 52-week test gave results, however, which are sufficiently uniform in range to warrant their acceptance and therefore no check tests were run. B_{30} is similar to B_{20}, the average results being somewhat higher. B_{10} seems to give the most consistent results of any of the cements in this series in point of range in strength developed, although its average strength is the lowest. The average strength of B_{40} is about 6400 pounds per square inch over the entire period of testing. Table X is similar to Table IX.

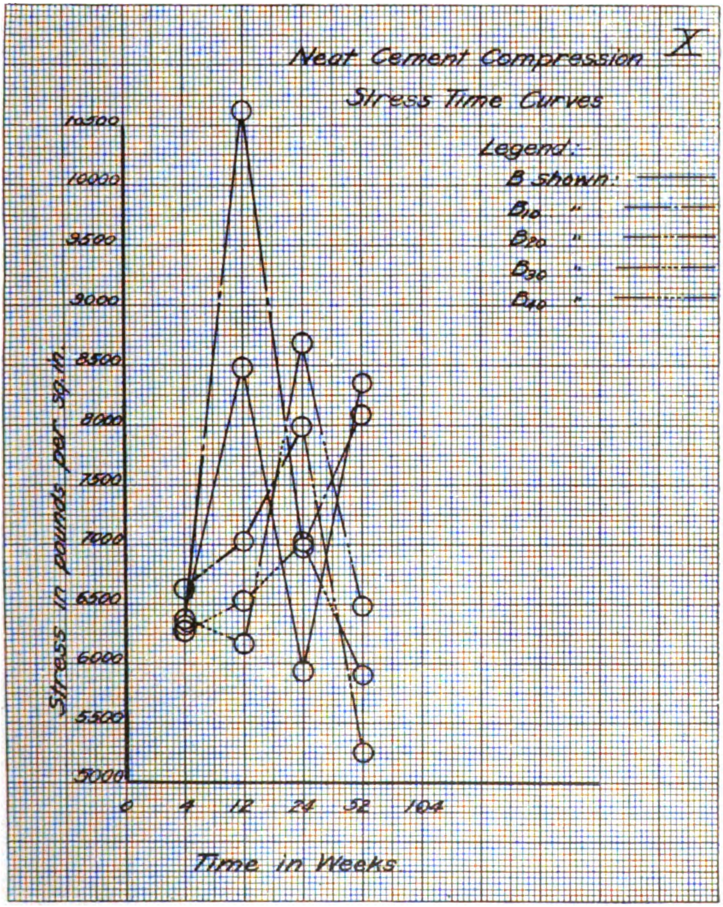

Neat Cement Compression
X
Stress Time Curves
Legend:-
B shown:
B_{10} "
B_{20} "
B_{30} "
B_{40} "
Stress in pounds per sq. in.
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
0
4
12
24
52
104
Time in Weeks

TABLE X

RELATIVE STRENGTHS

Age of test in weeks	4	12	24	50
B	3	2	5	1
B_{10}	2	1	3	2
B_{20}	1	3	2	5
B_{30}	3	5	1	3
B_{40}	5	4	4	4

In point of relative strength B_{10} seems to rank first. Since "B" and B_{20} have the same relative strengths during the entire period of testing, there is but little preference between them for second relative rank. B_{30} assumes fourth place, and B_{40}, fifth; this distinction, however, is not well definied; in point of excellence there seems to be but little real preference between cements B, B_{10}, B_{20}, and B_{30}. B_{40} is on the average probably somewhat inferior in strength to the others, but this inferiority is not pronounced.

Curve Sheet XI is similar to IX, differing only in the commercial cements used. The results here plotted are those obtained from tests of Red Ring Portland Cement "C" and blended cements of the same. (See Table "C", Appendix). Were it not for the high strength attained at the 24-week period by Cement C_{20}, the curves here shown might seem to indicate that the various cements behave in a more or less uniform manner. The maximum strength in each case was developed at 24 weeks, with an accompanying falling off in strength at the test period of 52 weeks.

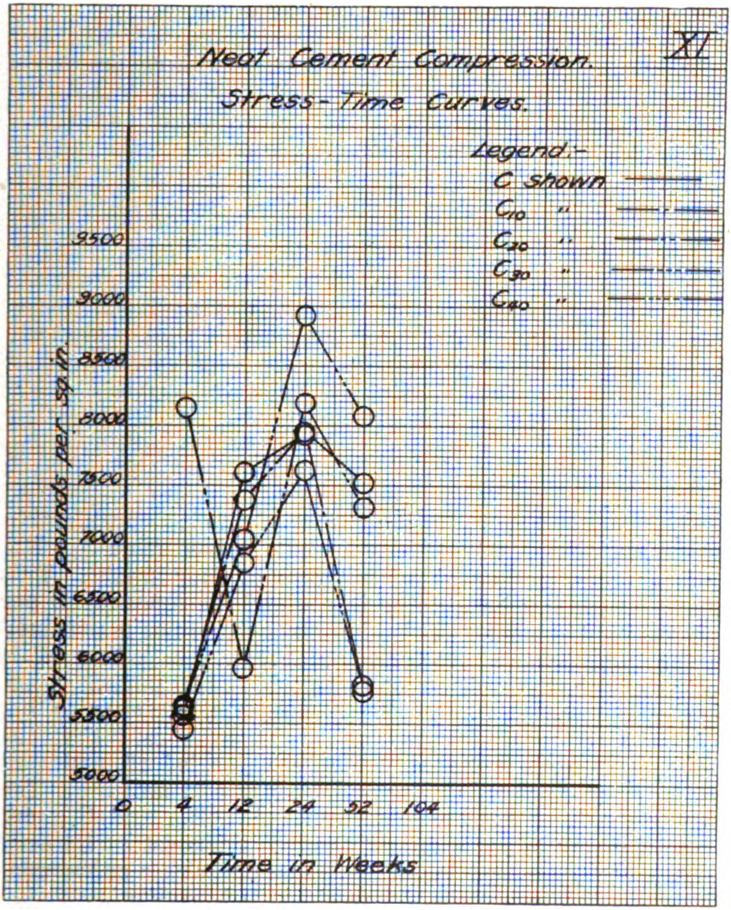
Table XI is similar to Table IX.

TABLE XI

RELATIVE STRENGTHS

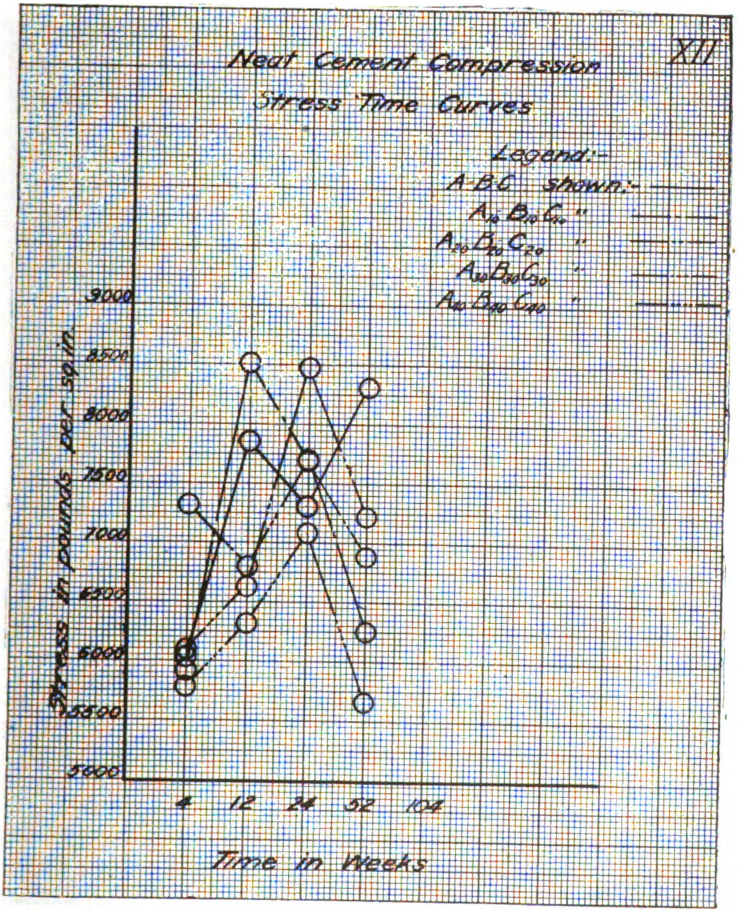
Age of test in weeks	4	12	24	52
C	4	1	3	2
C_{10}	2	2	4	4
C_{20}	1	5	2	3
C_{30}	3	3	1	1
C_{40}	5	4	5	5

The above table, like the two previous ones, shows so much variation that it is problematical whether it has much real significance From this table and in conjunction with


XI
Neat Cement Compression.
Stress-Time Curves.
Legend:-
C shown
C10 "
C20 "
C30 "
C40 "
Stress in pounds per sq. in.
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
0
4
12
24
52
104
Time in Weeks

Curve Sheet XI the following relative classification is made: It is seen that cement C_{30} is far superior to the other tests at the 24 and 52-week periods and is therefore given first relative rank. There is but little choice between C, C_{10}, and C_{20}, but should a distinction be made it is probable that "C" should receive second place, C_{20}, third; and C_{10}, fourth. C_{40} ranks fifth in relative importance.

Curve Sheet XII is similar to Curve Sheet VIII in that the results plotted are the average of the three brands of commercial cement and the averages of the corresponding blended cements. (See Table "C" "Average of averages," Appendix). This sheet shows the average results of neat cements in compression and is intended to represent such results as may be expected from an average Portland Cement and blended cements from the same. Here, as with the results which have been averaged, inconsistencies appear, but in less degree than these have been previously noted to occur. From averaging the results from testing commercial cements A, B, and C, it is seen that the strength increases satisfactorily up to the 24-week period, after which there is a falling off in strength. This is not excessive, however, and a complete recovery is noted at the 52-week test-period. In averaging the results of tests of A_{10}, B_{10}, C_{10} an unusual increase is noted up to the 12-week period of testing. The succeeding tests, however, fall off very markedly, the strength at 52 weeks being considerably lower than that at 24. The averages obtained from A_{20}, B_{20}, and C_{20} show rather high strengths at four weeks. This characteristic has been noted in each of the separate 20 per cent blended cements. This high strength is not maintained at the twelve-week test-period, although the falling off is not excessive, the unit stress being about 500 pounds; a recovery is noted at 24 weeks with an accompanying falling off at the 52-week test-period. It may be said that the average strength throughout the entire period of testing of this average cement is suite satisfactory and uniform. The results obtained from averaging the A_{30}, B_{30}, and C_{30} give a curve which is not unusual, there is a consistent increase in strength up to and including 24 weeks with a subsequent reduction in strength at 52 weeks. This reduction is not excessive and a further increase may be expected at the age of two years. The results of the two years tests will be watched with interest. The average results of A_{40}, B_{40}, C_{40} give a curve which is quite similar to A_{30}. B_{30}, C_{30}, the results obtained at any period of testing, however, being somewhat lower. The relative comparison of strengths is inter-


XII
Neat Cement Compression
Stress Time Curves
Legend:-
A-B-C shown:-
A10 B10 C10 "
A20 B20 C20 "
A30 B30 C30 "
A40 B40 C40 "
9000
8500
8000
7500
7000
6500
6000
5500
5000
Stress in pounds per sq.in.
4
12
24
52
104
Time in Weeks

esting. This is afforded by a study of Table XII, which is similar to the other tables of relative strength previously alluded to.

TABLE XII

RELATIVE STRENGTHS

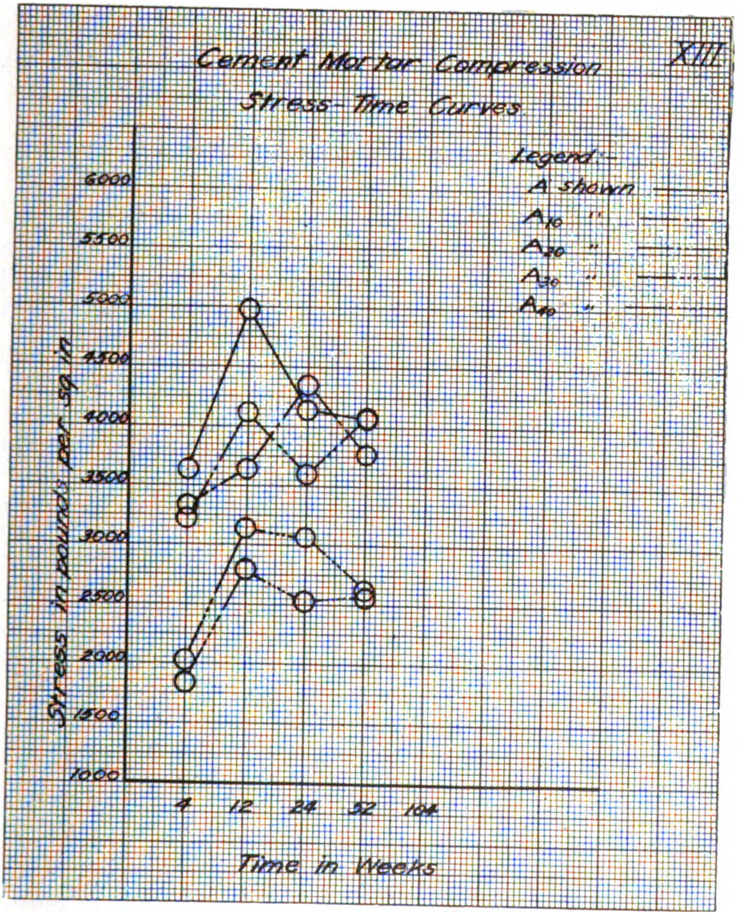
Age of test in weeks	4	12	24	52
A B C	3	2	4	1
A_{10} B_{10} C_{10}	4	1	2	4
A_{20} B_{20} C_{20}	1	3	2	3
A_{30} B_{30} C_{30}	2	4	1	2
A_{40} B_{40} C_{40}	5	5	5	5

By reference to the above table and Curve Sheet XII, the following relative comparison is made. In reverse order it is noted that the average of cements A_{40}, B_{40}, C_{40} is consistently lowest in strength and therefore is classified fifth. Due to the falling off in strength at the 24 and 52-week periods, the average of cements A_{10}, B_{10}, C_{10} is given fourth rank in relative importance. Of the three remaining averages, there is scarcely sufficient variation in strengths to warrant relative differentiation. The averages of the 30 per cent blended cements show a slight increase over the 20 per cent averages, the falling off in strength at the 12-week period is against the latter, and the greater strength developed in the former at the later periods may warrant the average of A_{30}, B_{30}, C_{30} being classified ahead of the average of A_{20}, B_{20}, C_{20}. No effort is made to differentiate between the average results of A, B, C, and A_{30}, B_{30}, C_{30}.

It should be noted throughout these tests in compression that while irregularities occur they are not confined to the blended cements. The Portland Cements manifest eccentricities difficult to explain. The results were not all that was expected, but if they have been interpreted aright they indicate that the blended cements compare faborably with the Portland Cements in tests for neat compression.

(D) Cement Mortar in Compression.

The American Society for Testing Materials, in the revision of standard specifications and tests for Portland Cement, proposed the addition of a test which has not hitherto been required, namely, a test for compressive strength of Portland Cement mortar. (See proceedings of the American Society for Testing Materials Vol. 16, page 590.) It is


Cement Mortar Compression
Stress-Time Curves
XIII
Legend:-
A shown
A10 ''
A20 ''
A30 ''
A40 ''
Stress in pounds per sq in
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
4
12
24
52
104
Time in Weeks

proposed that the average strength in pounds per square inch of not less than three standard test pieces composed of one part of cement and three parts of sand, by weight, shall be equal to or greater than 1200 pounds per square inch at the age of seven days and 2000 pounds per square inch at the age of 28 days, the specimens having been stored one day in moist air the remaining time in water. It is proposed that the test pieces be cylinders 2 inches in diameter and 4 inches high. The results herein reported differ from the above suggestions only in the method of manufacture and in the height of cylinders. The specimens used were 2 inches high instead of 4 inches, as recommended. It should be noted that these specimens were prepared before the appearance of the tentative revisions of the American Society for Testing Materials. No tests were made at seven days.

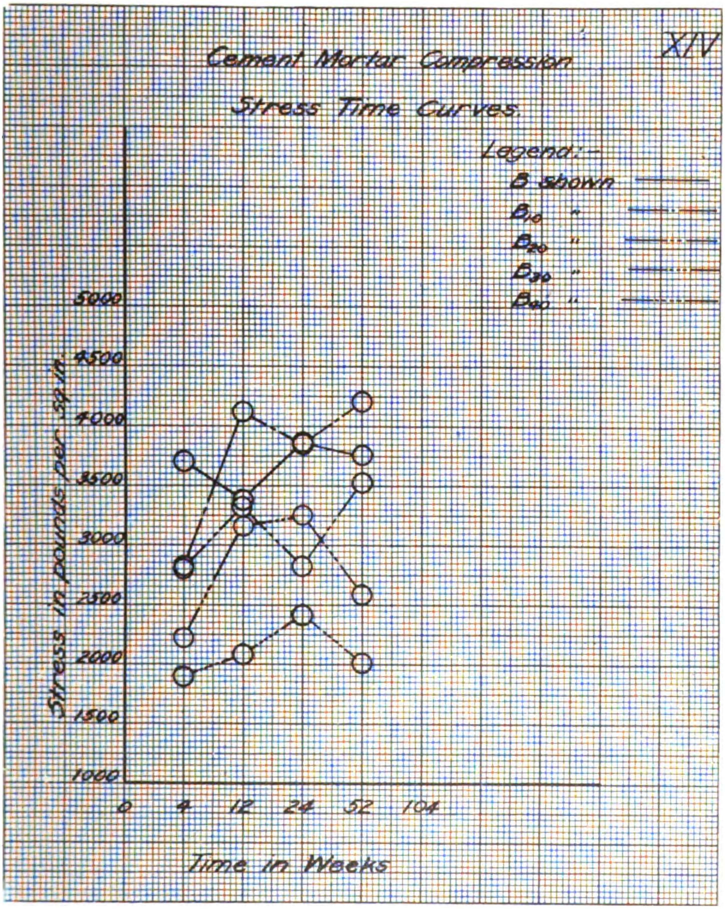
On Curve Sheet XIII are plotted the results obtained from testing mortar specimemts of Atlas Portland Cement "A" and blended cements of the same. (See Table "C" Appendix). The strengths obtained increased consistently during the first 12 weeks and with but one exception, (A_{40}), atained strengths greater than 2000 pounds per square inch at 28 days (the proposed requirements as noted above. With the exception of A_{10} all cements attain their maximum strength at 12 weeks, A_{10} attaintaining it at 24 weeks. A relative comparison in strength is afforded by Table XIII, which is similar to the previous tables.

TABLE XIII

RELATIVE STRENGTHS

Age of test in weeks	4	8	12	24
A	1	1	2	1
A_{10}	2	3	1	3
A_{20}	3	2	3	1
A_{30}	4	4	4	4
A_{40}	5	5	5	5

Cement "A" seems to have attained the highest relative strength throughout the period of testing although after the 12 week tests this classification is not so pronounced. There is but little choice between A_{10} and A_{20} and these are easily superior to A_{30} and A_{40}, the latter receiving fourth and fifth places respectively in relative strengths.


XIV
Cement Mortar Compression
Stress Time Curves.
Legend:—
B shown
B_{10} "
B_{20} "
B_{30} "
B_{40} "
Stress in pounds per sq.in.
5000
4500
4000
3500
3000
2500
2000
1500
1000
0
4
12
24
52
104
Time in Weeks

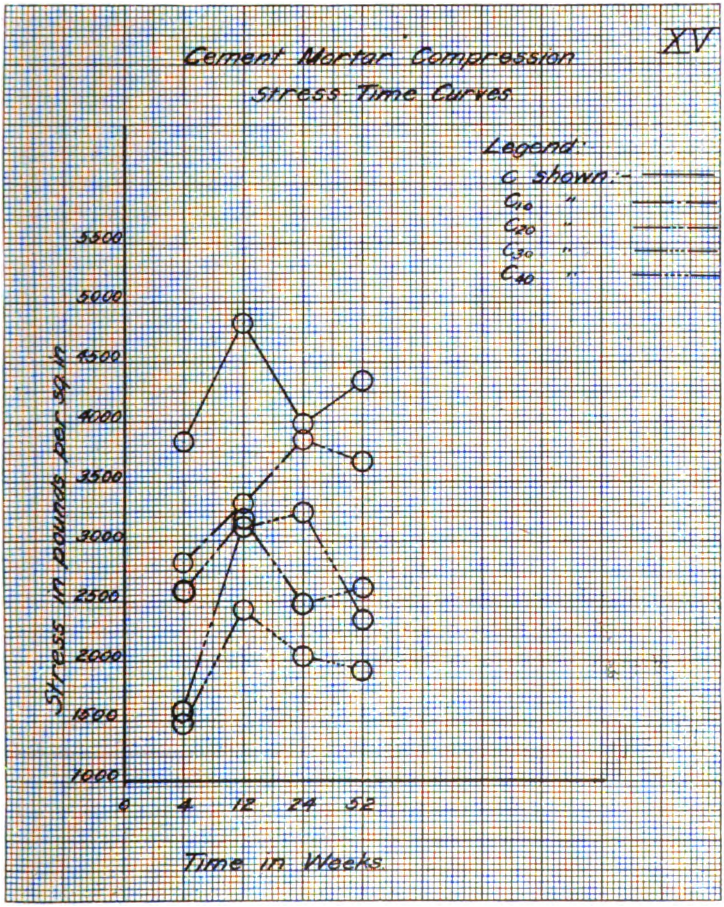
Curve Sheet XIV is similar to Curve Sheet XIII, the results plotted being attained from compressive tests of mortar specimens of Lehigh Portland Cement "B" and blended cements of the same. (See Table "C" Appendix). The results shown, with the exception of Cement B_{40} satisfy the proposed requirements, as has been previously noted, of the American Society for Testing Materials at 28 days. There is not quite the same consistency in results here as is shown on Curve Sheet XIII. Cement "B" shows a loss in strength at 12 weeks. This loss is not excessive and is overcome as shown in the 24 and 52-week tests. Cement B_{10} shows rather more uniform results than does A_{10} and the strengths attained average somewhat higher. The curve B_{20} attains the highest strength at 12 weeks with an accompanying falling off at 24. The maximum strength, however, is attained at 52 weeks, the average strength of this cement throughout the entire period of testing is quite high, being about 3100 pounds per square inch. A consistent increase in strength is shown in the results of B_{30}, up to 24 weeks when the maximum strength is attained. The loss at 52 weeks, however, is not excessive nor unusual. Cement B_{40} shows rather lower strengths at all periods of testing than do the other cements, the curve is quite uniform, however, and is probably quite representative of cement mortars having such high percentages of blending material in the cement. Table XIV is similar to Table XIII.

TABLE XIV

RELATIVE STRENGTHS

Age of test in weeks	4	12	24	52
B	1	2	1	2
B_{10}	2	1	1	1
B_{20}	3	3	4	3
B_{30}	4	4	3	4
B_{40}	5	5	5	5

A study of the above table in conjunction with Curve Sheet XIV shows but little choice between Cements "B" and B_{10}, but a slight preference at the early periods of testing for the former seems to be warranted. At the later periods, however, the preference is reversed. In consequence, the following classification is given: Cement B_{10} ranks first; "B", second; B_{20}, third; B_{30}, fourth; and B_{40}, fifth.


XV
Cement Mortar Compression
Stress Time Curves
Legend:
C shown:-
C10 "
C20 "
C30 "
C40 "
Stress in pounds per sq in
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
0
4
12
24
52
Time in Weeks

Curve Sheet XV shows the plotted results of mortar compression tests of Red Ring Portland Cement "C" and the blended cements of the same. (See Table "C", Appendix).

A wide range in the results obtained in this series of tests characterizes this curve sheet. The values obtained by Cement "C" are uniformly high; those by C_{40} are low; the difference in strength averages about 2300 pounds per square inch throughout the entire period of testing. It is felt that this range is probably excessive. Separately, the curves may be considered quite satisfactory. Curve "C" attaining a maximum strength at twelve weeks with a reduction at 24, followed by a gain at 52 weeks. Curve C_{10} consistently increases in strength to a maximum at 24 weeks with a slight reduction in strength at 52 weeks. Curve C_{20} is similar to Curve "C" in outline; the strengths developed in the former range about two-thirds of those of the latter. The results of testing C_{30} give a curve which is in no sense unusual, a consistent increase in strength being noted up to twenty-four weeks with a slight falling off in the 52-week test. Curve C_{40} is consistently lower in strengths than the other curves. Table XV is similar to the previous tables of relative strengths.

TABLE XV

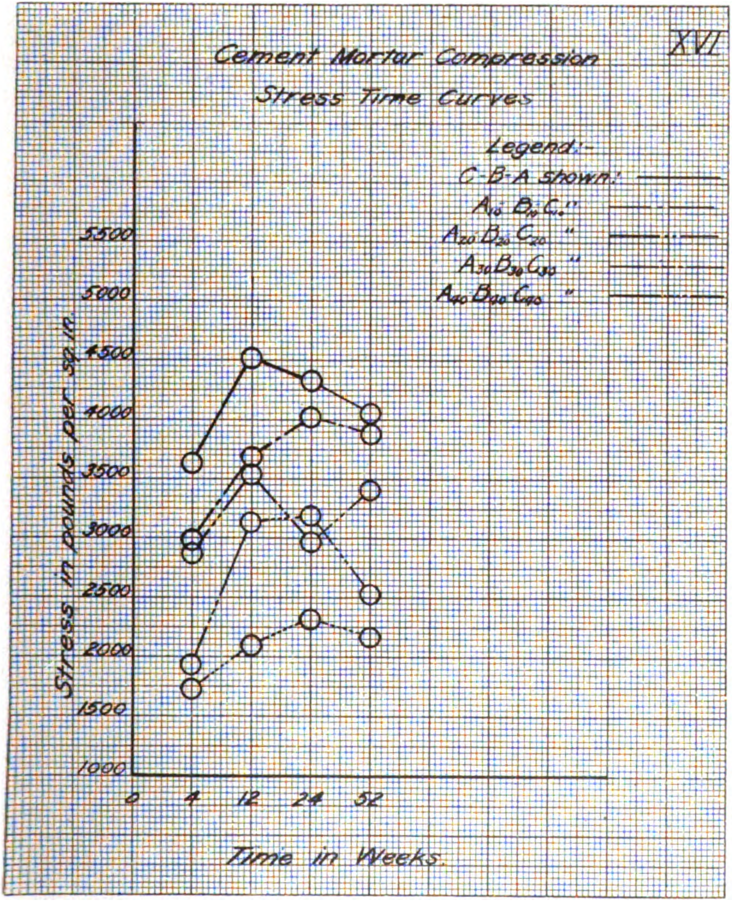
RELATIVE STRENGTHS

Age of test in weeks	4	12	24	52
C	1	1	1	1
C_{10}	2	2	2	2
C_{20}	3	3	4	3
C_{30}	4	4	3	4
C_{40}	5	5	5	5

The above table shows an easy comparison of relative strengths, the strengths decreasing as the blending material increases. The mortar from the commercial Portland Cement ranks higher in strength throughout the entire period of testing.

The results obtained from averaging the corresponding tests of the three previous curve sheets are plotted on Curve Sheet XVI. (See Table "C", "Average of averages," Appendix).

It will be noted that the results of tests of mortar specimens from the 40 per cent blended cements are relatively low, falling below the requirements of the proposed specifi-


XVI
Cement Mortar Compression
Stress Time Curves
Legend:-
C-B-A shown:
A_{10} B_{10} C_{10} "
A_{20} B_{20} C_{20} "
A_{30} B_{30} C_{30} "
A_{40} B_{40} C_{40} "
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
Stress in pounds per sq. in.
0
4
12
24
52
Time in Weeks.

cations of the American Society for Testing Material. Results from the tests of the 30 per cent blended cements reveal higher strengths than those of the 40 per cent but in this case the requirements of the proposed specifications of the American Society for Testing Materials are not satisfied, the strengths being about 60 pounds per square inch less than the requirements at 28 days. The results from the 10 and 20 per cent blended cement mortars are well within the specifications referred to and are quite satisfactory in strength throughout the entire period of testing. A relative comparison is made from Curve Sheet XVI. Here is it easily seen that the strengths developed throughout the entire period of testing vary inversely with the amount of blending material used in an almost direct ratio.

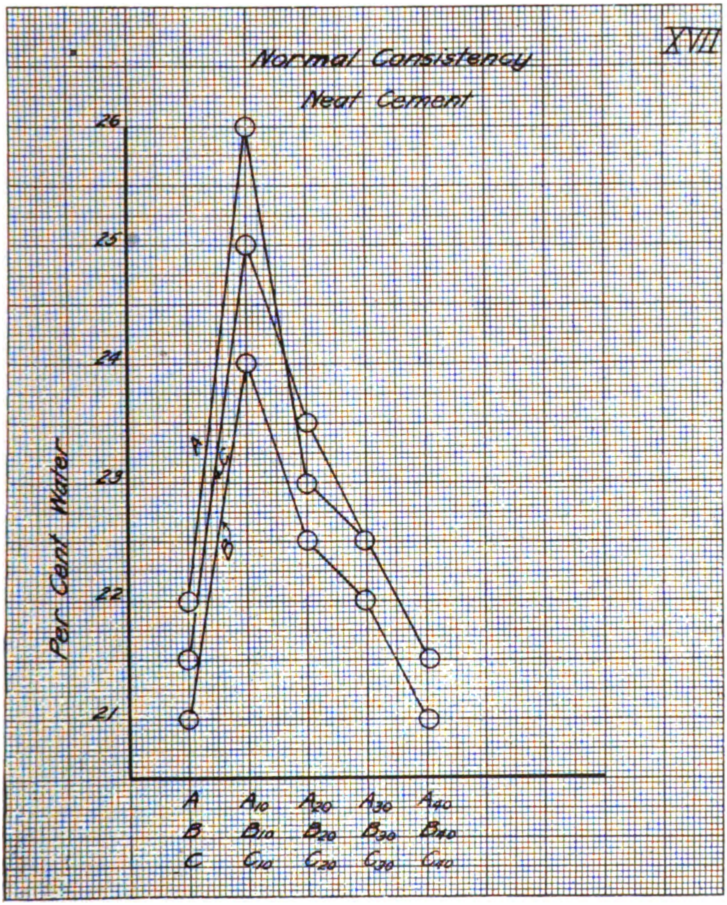
(E) Normal Consistency.

The amount of water required to bring the various cement pastes to normal consistency is plotted on Curve Sheet XVII. (See Table D, Appendix). As would be expected, the amount of water increases rapidly from that required for Portland Cement to that required for the 10 per cent blended cement. For, as has been previously stated, the latter carries a higher percentage of the extremely fine Portland Cement than does the former, and in consequence should demand more water if the same degree of hydration is to take place. As the percentage of the blending material increases, the amount of water required should decrease and this assumption is clearly shown to be correct by the accompanying curve sheet.

It was assumed in preparing the blended cements that about 30 per cent of the Portland Cement was removed, that which was retained on a No. 200 sieve being at least that amount. The sifting was not continued to the extent that would be required in a test for fineness. It is not unusual, then, that the 30 per cent blended cement requires approximately the same amount of water for normal consistency as the Portland Cement. As the percentage of water required for normal consistency for mortar specimens was obtained from the standard conversion tables of the specifications of the United States Government for Portland Cement mortar, the characteristics noted above apply also to mortar as well as to cement paste.

(F) Time of Setting.

The time required to produce initial and final setting was determined with the Vicat apparatus, and is shown plotted on Curve Sheets XVIII and XIX, respectively. It is tabulated in Table D of appendix. It is significant that


XVII
Normal Consistency
Neat Cement
26
25
24
23
22
21
Per Cent Water
A
C
B
A
A10
A20
A30
A40
B
B10
B20
B30
B40
C
C10
C20
C30
C40

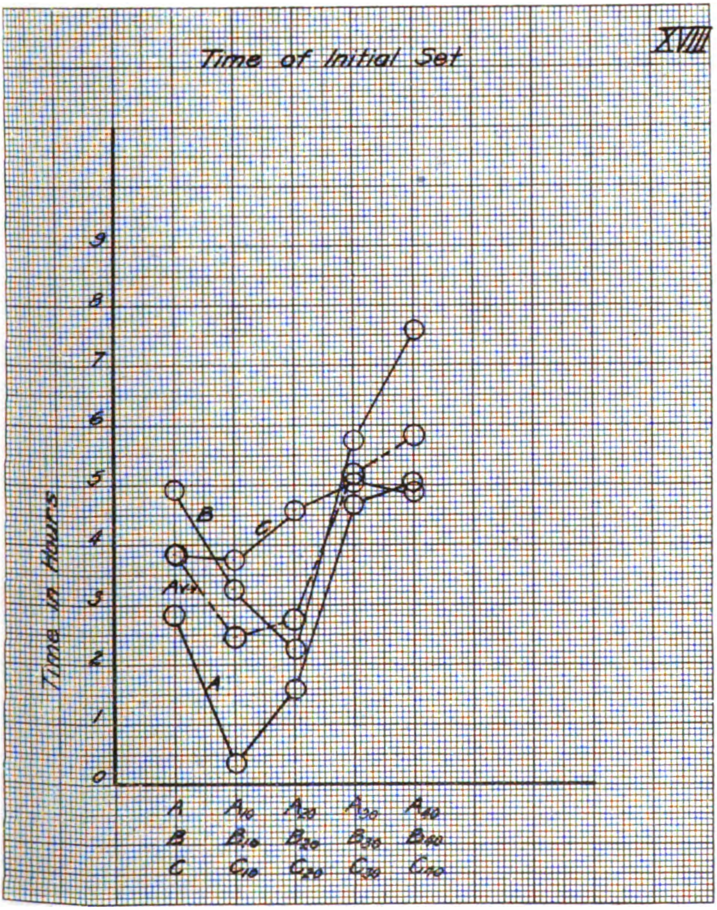
the time of setting is less in a case of the 10 per cent blended cements than with the Portland Cements. As the percentage of blending material increases, the time of setting increases until, when a blending material of between 20 and 30 per cent has been used, the time of setting of the blended cement is equal to that of the Portland Cement. The 40 per cent blended cements are somewhat slower in setting than the Portland Cements.

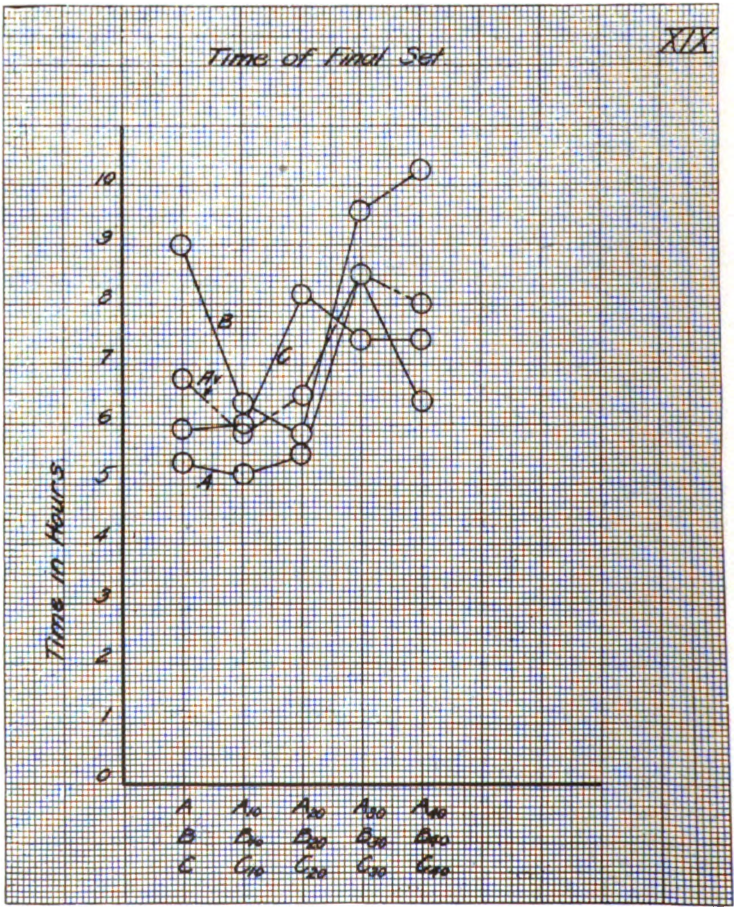
(G) Constancy of Volume.

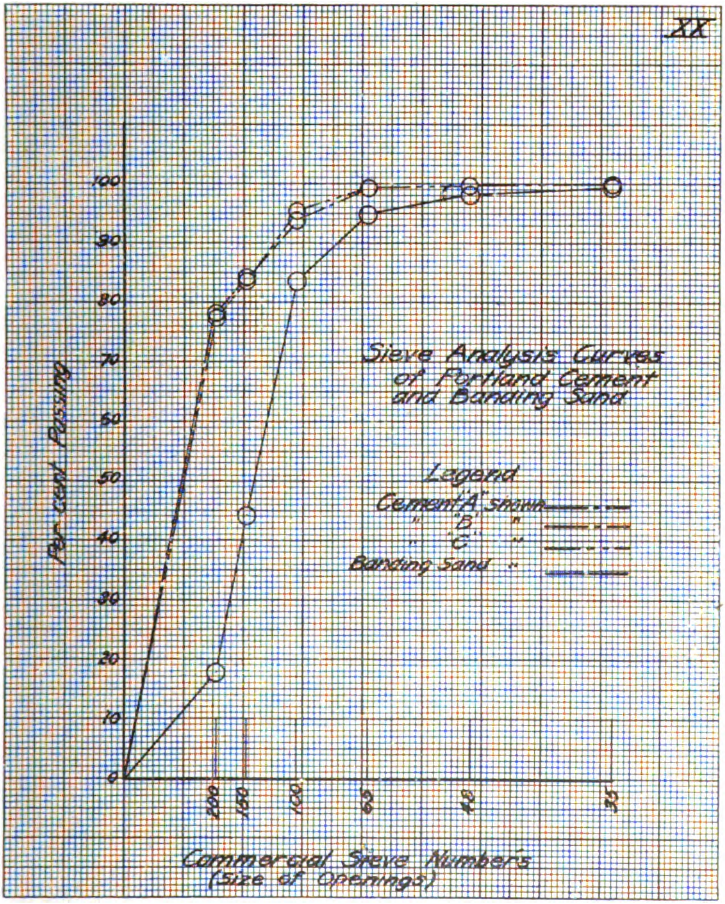
The usual tests, normal and accelerated, for the determinations of soundness were made. The standard methods suggested by the American Society of Civil Engineers were followed in these tests. The specimens were observed for periods of one year and in every instance the standard specifications were fulfilled. Each of the specimens remained true and sound throughout this entire period.

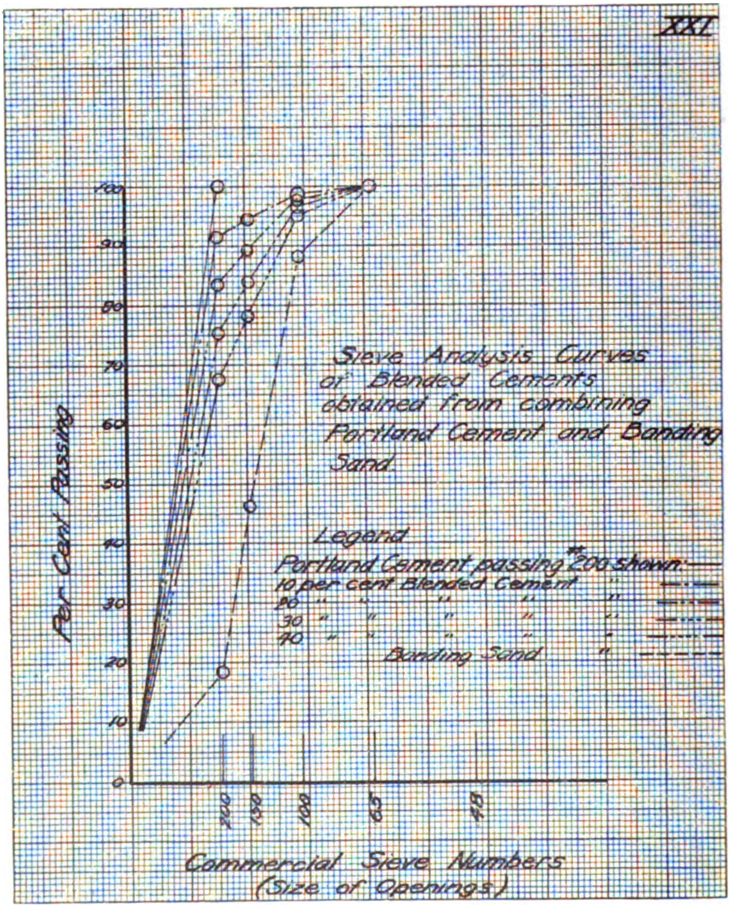
(H) Fineness and Sieve Analysis.

The curves of sieve analysis shown on Sheet XX were plotted from the data compiled in Table "D" (Appendix). It will be noted that the fineness of these Portland Cements easily satisfied the specifications of the American Society for Testing Materials and that there was but little difference in the gradation of the size of particles, cements A and B having almost identical curves of sieve analysis. The banding sand is shown to be well graded between the No. 65 and No. 200 sieves, this portion of the curve comparing favorably with the same portion of the Portland Cement curves. By combining this cement and sand, as has been previously indicated, that is, by using only that portion of the cement passing the No. 200 sieve and that portion of the sand passing the No. 65 sieve, a combined curve can be obtained which is quite similar to the Portland Cement curves. Curve Sheet XXI, therefore, has been prepared showing the gradation of the Portland Cement after the removal of the coarse particles (those retained upon a No. 200 sieve) and of the banding sand after the removal of particles larger than the No. 65 sieve openings. The combinations of these are shown as combined curves and are typical of the gradation of the blended cements. It will be noted here that the blended cement containing 30 per cent of sand has a gradation in size of particles almost identical with that of the Portland Cements. The data plotted on Curve Sheet XXI were computed but it is thought that they should reasonably approximate experimentally derived data.


XVIII
Time of Initial Set
Time in Hours
9
8
7
6
5
4
3
2
1
0
B
C
Avr.
A
A
B
C
A_{10}
B_{10}
C_{10}
A_{20}
B_{20}
C_{20}
A_{30}
B_{30}
C_{30}
A_{40}
B_{40}
C_{40}


XIX
Time of Final Set
Time in Hours
10
9
8
7
6
5
4
3
2
1
0
B
C
Av
A
A
B
C
A_{10}
B_{10}
C_{10}
A_{20}
B_{20}
C_{20}
A_{30}
B_{30}
C_{30}
A_{40}
B_{40}
C_{40}


XX
Sieve Analysis Curves of Portland Cement and Banding Sand
Legend
Cement "A" shown
" "B" "
" "C" "
Banding Sand "
Per cent Passing
100
90
80
70
60
50
40
30
20
10
0
200
150
100
65
48
35
Commercial Sieve Numbers (Size of Openings)


XXI
Sieve Analysis Curves of Blended Cements obtained from combining Portland Cement and Banding Sand
Legend
Portland Cement passing #200 shown: ——
10 per cent Blended Cement "
20 " " " " "
30 " " " " "
40 " " " " "
Banding Sand "
Per Cent Passing
0
10
20
30
40
50
60
70
80
90
100
200
150
100
65
48
Commercial Sieve Numbers
(Size of Openings)

(I) Chemical Analysis and Specific Gravity.

The chemical analyses recorded in Table XVI are partly laboratory determinations and partly determinations arrived at by computation. The three commercial Portland Cements and the Banding Sand were analyzed by Mr. R. P. Rinker, Chemist for the Missouri Bureau of Geology and Mines, through the courtesy of Mr. H. A. Buehler, Director. Analyses were furnished by the various cement companies. The results obtained by Mr. Rinker and those furnished by the cement companies are so nearly identical that only those of the former are shown. The analyses of the various blended cements are the results of combining the analysis of the banding sand with the analysis of the Portland Cement blended in the ratio of the combination, sand to cement.

SUMMARY

In summarizing the foregoing, the following observations have been noted:

(A) Neat Cement in Tension.

Portland Cement and blended cements gain in strength at approximately the same rate.

Portland Cement develops slightly greater strength at early periods of testing than does a blended cement.

At 24 and 52 weeks the 30 and 40 per cent blended cements are equal in strength to the Portland Cement, the 10 and 20 per cent blended cements showing to slightly less advantage.

(B) Cement Mortar In Tension.

The rate of gain in strength in Portland Cement mortar and blended cement mortar is approximately the same.

Within the scope of this investigation Portland Cement mortar is not superior in strength to blended cement mortar.

When the amount of blending material used does not exceed 30 per cent, blended cement mortar develops greater strength than does Portland Cement mortar.

(C) Neat Cement In Compression

The results obtained are unsatisfactory, owing to lack of uniformity.

When the amount of blending material used does not exceed 30 per cent, the relative strength of the blended cements compares favorably with that of commercial Portland Cement.

(D) Cement Mortar In Compression.

Within the scope of these tests Portland Cement mortar develops greater strength than does blended cement mortar.

The strength of mortar varies inversely with the amount of blending material used.

When the amount of blending material does not exceed about 30 per cent, such blended cement mortar may be expected to pass satisfactorily the proposed specifications of the American Society for Testing Materials.

Note:—It seems unusual that the results obtained from testing cement mortars in tension are so contradictory to those obtained from testing similar cement mortars in compression; the former favoring the blended cements, while the latter show the Portland Cements to be superior in strength.

(E) Normal Consistency.

Within the scope of this investigation, Portland Cements differ in normal consistency within narrow limits.

The normal consistency of blended cements varies inversely with the amount of the blending material used.

(F) Time of Setting.

Within the scope of this investigation, Portland Cements differ in time of setting within wide limits.

Blended cements, having more than 20 per cent of blending material, seem to develop initial and final setting more slowly than do the Portland Cements of which they are composed.

Blended cements, having not to exceed 40 per cent of blending material, satisfy the requirements of the present standard specifications for the time of setting of Portland Cements.

(G) Constancy of Volume.

Blended cements, having not to exceed 40 per cent of blending material, satisfactorily meet the present standard specifications of Portland Cements for soundness.

(H) Fineness and Sieve Analysis.

Of the blended cements, those containing 30 per cent of sand most nearly approximate the Portland Cements in fineness and gradation of size of particles.

CONCLUSIONS

Portland Cements, of a fineness sufficient to pass a No. 200 sieve, may be blended as much as 40 per cent, by weight, with quartz sand, the latter of a fineness sufficient to pass a No. 65 sieve but not fine enough to permit of more than 20 per cent to pass a No. 200 sieve, and the resulting blended cement will satisfactorily pass the requirements of the present standard specifications for Portland Cement of the American Society for Testing Materials.

Quartz sand is a satisfactory substitute for the inert clinker particles in Portland Cement in maintaining the present physical characteristics of the latter, when used in amounts not to exceed 30 per cent, by weight.

Note: It is obviously impracticable to manufacture blended cements commercially in a manner followed in this investigation. It is thought to be feasible, however, to accomplish this end by incorporating the sand in the cement just prior to final grinding. Such procedure, it is thought, would have several advantages over the methods used here. It is thought that the reduction of the cement clinker in fineness much in excess of that attained at present would result and also that a more thorough mixing of the sand and cement would be accomplished than by any other method. With a view of ascertaining to what extent these assumptions are correct and also to what extent the blending of Portland Cement with quartz sand may be carried, an investigation has been started in which the Portland Cement is mixed with the sand in a tube mill and the grinding continued until a high percentage of the cement clinker is reduced to cement. The results of this investigation will appear in a subsequent bulletin.

CHEMICAL ANALYSIS AND SPECIFIC GRAVITY

Analysis of Cements

Cement Serial Number	Ignition Loss	Percentage of:							Sp. Gr.	
		SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Total	Computed	Determine
A	1.80	21.48	2.57	5.89	63.32	3.00	1.50	100.06		3.184
A_{10}	1.65	29.64	2.28	5.30	56.97	2.70	1.30	99.90	3.135	
A_{20}	1.50	37.31	2.02	4.86	50.66	2.40	1.20	99.95	3.084	
A_{30}	1.35	44.88	1.89	4.33	44.33	2.10	1.05	99.93	3.033	
A_{40}	1.21	52.65	1.66	3.81	38.01	1.80	0.90	100.04	2.984	
B	1.80	21.46	2.85	6.81	63.56	2.10	1.46	100.04		3.176
B_{10}	1.65	29.18	2.59	6.20	57.21	1.89	1.31	100.03	3.126	
B_{20}	1.50	36.90	2.31	5.58	50.85	1.68	1.17	99.99	3.076	
B_{30}	1.35	44.62	2.09	4.97	44.49	1.47	1.02	100.01	3.028	
B_{40}	1.21	52.32	1.83	4.36	38.14	1.26	.87	99.99	2.977	
C	0.60	22.70	3.07	7.55	63.58	1.22	1.53	99.85		3.208
C_{10}	.57	30.08	2.79	6.87	56.80	1.09	1.37	99.57	3.155	
C_{20}	.54	37.88	2.51	6.18	50.61	.97	1.22	99.91	3.102	
C_{30}	.52	45.49	2.24	5.49	44.21	.85	1.07	99.87	3.049	
C_{40}	.49	53.08	1.96	4.81	37.91	.73	.91	99.89	2.996	
Banding Sand	.32	98.66	.31	.69	.04			100.02		2.681

RESULTS OF TENSION TESTS

(Neat Specimens)

Series No.	Specimen made 1915	24 hours	7 days	28 days	56 days	84 days	24 weeks	52 weeks	104 weeks
		295	743	843	769	755	830	671	
B	12-20	325	812	784	783	943	635	686	
		312	768	861	722	875	696	739	
Avr.		317	779	855	758	789	744	728	
		311	797	802	802	912	762	687	
B	12-20	325	812	784	783	943	635	686	
		282	835	878	815	784	768	670	
Avr.		306	815	821	801	883	722	681	
		400	710	758	758	711	590	642	
C	12-20	405	612	790	727	737	647	562	
		375	745	789	788	788	673	511	
Avr.		393	686	779	758	745	636	572	
		325	637	635	677	679	627	610	
A_{10}	12-23	332	463	674		736	583	598	
		308	512	738	656	719	557	560	
Avr.		322	537	682	666	711	589	589	
		388	544	645	791	714	683	677	
B_{10}	12-23	370	721	753	793	761	675	617	
		340	712		790	651	676	553	
Avr.		366	666	699	792	708	678	616	
		320	521	765	662	686	635	412	
C_{10}	12-22	295	648	751	724	688	593	414	
		288	720		713	610	600	485	
Avr.		301	630	758	700	681	608	434	
		235	777	755	745	763	731	640	
A_{20}	12-27	274	733		680	764	774	633	
		220	745	675	789	792	720	765	
Avr.		243	752	715	738	773	742	679	
		323	716	900	750	784	776	590	
B_{20}	12-27	364	726	902	662	796	747	554	
		320	759	777	794	797	706	552	
Avr.		332	733	859	735	792	743	565	
		327	561		620	714	686	551	
C_{20}	12-27	314	603	613	623	672	626	487	
		277	667	652	600	724	579	498	
Avr.		306	610	622	614	703	630	512	
		225	622	744	872	747	726	762	
A_{30}	12-29	303	680	820	865	777	790	675	
		305	670	750	812	674		776	
Avr.		278	657	771	849	732	758	738	
		249	630	797	714	720	775	776	
B_{30}	12-29	272	730	731	830	688	682	697	
		255	593	762	778	700	765	717	
Avr.		259	651	763	774	702	741	730	
		182	579	664	784	577	620	622	
B_{30}	12-28	177	559	544	730	627	702	580	
		175	634	615	620	618	658	564	
Avr.		178	591	607	711	607	660	588	
		325		777	767	797	736	735	
A_{40}	12-30	300	629	791	759	725	781	690	
		305	694	693	719	793	765	743	
Avr.		310	662	754	748	771	761	722	
		265	583	651	735	748	633	644	
B_{40}	12-29		482	685	775	705	743	697	
			576	631	820	682	704	702	
Avr.		265	547	655	777	711	693	681	
		186	525	560	730	628	679	606	
C_{40}	12-30	208	525	678	679	611	661	616	
		205	485	672	711	694	603	639	
Avr.		200	511	637	706	644	648	618	
Average of Averages									
A - B - C		335	760	818	772	806	701	660	
A_{10} - B_{10} - C_{10}		330	611	713	719	700	625	546	
A_{20} - B_{20} - C_{20}		294	692	732	702	756	705	585	
A_{30} - B_{30} - C_{30}		238	633	714	778	780	720	685	
A_{40} - B_{40} - C_{40}		258	573	682	758	709	701	673	
Average of Highest Breaks									
A - B - C		358	802	843	759	869	757	701	
A_{10} - B_{10} - C_{10}		347	693	752	731	728	648	590	
A_{20} - B_{20} - C_{20}		322	713	770	735	771	745	635	
A_{30} - B_{30} - C_{30}		253	681	760	829	708	756	725	
A_{40} - B_{40} - C_{40}		266	601	718	772	746	734	694	

RESULTS OF TENSION TESTS

(Mortar Specimens)

Series No.	Spec's made 1915-1916	Stress in Pounds per Square Inch						
		7 days	28 days	56 days	84 days	24 weeks	52 weeks	104 weeks
		192	257	340	339	313	278	
A	12-21	165	288	322	343	321	251	
		200	322	314	357	299	241	
Avr.		186	289	325	346	310	247	
		192	332	345	389	378	360	
B	12-21	175	348	381	402	362	340	
		224	339	383	361	369	366	
Avr.		197	339	369	384	369	355	
		213	362	392	462	445	365	
C	12-21	228	366	387	466	435	407	
		254	395	369	485		370	
Avr.		232	374	382	471	440	381	
		334	462	527	524	532	404	
A_{10}	12-31	337	443	428	476	475	411	
		343	375	428	523	452	374	
Avr.		338	427	461	508	486	396	
		311	413	412	449	432	481	
B_{10}	12-31	294	366	426	447	435	492	
		285	496	522	487	429	466	
Avr.		297	425	453	461	432	479	
		320	325	351	457		380	
C_{10}	12-30	230	304	414	511	523	504	
		273	337		416	390	326	
Avr.		274	322	383	461	457	403	
		308	417	475	389	441	400	
A_{20}	12-31	252	404	448	404	431	397	
		257	396	453	458	483	408	
Avr.		272	405	459	417	452	402	
		284	422	430	408	448	388	
B_{20}	12-31	299	405	400	476	421	400	
		218	428	439	462	434	384	
Avr.		277	418	423	448	434	391	
		273	460	373	426	373	389	
C_{20}	12-31	257	416	427	491	375	388	
		268	381	455	468	411	392	
Avr.		266	419	418	462	386	389	
		220	381	400	484	413	370	
A_{30}	1-1	220	367	350	426	452	362	
		237	327	431	411	433	409	
Avr.		225	358	393	440	433	377	
		252	306	409	429	369	372	
B_{30}	1-1	232	346	344	361	437	343	
		262	350	435	451	403	383	
Avr.		248	334	396	413	403	366	
		248	365	346	444	417	354	
C_{30}	1-1	260	382	476	414	407	389	
		267	340	402	385	460	389	
Avr.		258	362	408	414	425	377	
		181	356	371	381	360	385	
A_{40}	1-1	221	339	356	364	357	298	
		203	328	354	302	337	309	
Avr.		201	341	360	349	351	331	
		187	318	308	372	342	314	
B_{40}	1-1	194	338	358	332	391	332	
		203	318	362	403	356	345	
Avr.		194	324	343	362	363	330	
		181	382	342	421	357	314	
C_{40}	1-1	218	362	375	392	387	329	
		185	352	360	409	386	326	
Avr.		194	365	359	407	373	323	
Average of Averages								
A - B - C		205	334	359	400	373	331	
A_{10} - B_{10} - C_{10}		303	391	432	477	458	426	
A_{20} - B_{20} - C_{20}		272	413	433	442	424	394	
A_{30} - B_{30} - C_{30}		244	351	399	422	420	373	
A_{40} - B_{40} - C_{40}		196	342	354	375	362	328	
Average of Highest Breaks								
A - B - C		226	355	372	415	381	350	
A_{10} - B_{10} - C_{10}		325	428	467	507	497	436	
A_{20} - B_{20} - C_{20}		293	435	456	475	447	366	
A_{30} - B_{30} - C_{30}		255	371	447	460	450	393	
A_{40} - B_{40} - C_{40}		208	359	369	402	379	352	

RESULTS OF COMPRESSION TESTS

Series No.	Spec'c made	Stress in pounds per Square Inch							
		4 weeks Neat	4 weeks Mortar	12 weeks Neat	12 weeks Mortar	24 weeks Neat	24 weeks Mortar	52 weeks Neat	52 weeks Mortar
		5480	3920	6490	5220	6930	5020	9188	3809
A		7220	3360	7060	4540	11050	3380	8945	3304
		5800	3620	8860	5170	6110	4020		5056
Avr.		6170	3633	7470	4980	8030	4140	9066	4456
		5280	3200	10380	3780	6470	4180	7984	3859
B		6850	3390	8380	4040	4440	5500	7898	4140
		6980	3700	6700	3380	6890	3860	9159	3252
Avr.		6370	3430	8487	3730	5930	4840	8347	3750
		4550	4060	6790	4720	7920	4200	6944	4350
C		6610	3920	6500	4680	8830	3550	8259	3772
		5520	3540	9520	5100	7050	4220	7337	4912
Avr.		5560	3840	7603	4830	7930	3990	7513	4345
		6590	3010	6250	2580	7780	4020	3844	3782
A - 10		6430	3420	6860	4630	8640	4510	5611	3679
		4400	3560	9520	3720	8060	4530	5245	3820
Avr.		5810	3330	7543	3640	8160	4350	4900	3760
		6120	2700	11000	3590	7220	4460	7961	4331
B - 10		6450	2900	9980	5070	6520	2840	7996	3327
		6400	2870	10860	3640	7160	4250	8314	4948
Avr.		6320	2823	10613	4120	6970	3850	8090	4202
		5500	2660	7980	4010	7690	2580	5615	3025
C - 10		4660	3320	6200	2710	7780	4660	5117	4537
		1110	8500	7940	3220	8380	4310	6565	3440
Avr.		5610	2827	7373	3310	7950	3850	5766	3667
		6280	3830	6200	4300	7230	4140	8143	3812
A - 20		6470	2950	6960	4280	5170	3870	7258	4069
		8700	2850	9070	3740	8350	2780	8888	4320
Avr.		7150	3210	7410	4110	6920	3600	8096	4067
		6450	3040	4800	3330	9120	2890	6464	3166
B - 20		6130	2750	8210	3430	7030	2550	5166	3720
		7340	2620	8070	3220	7830	3040	4149	3700
Avr.		6640	2803	7026	3330	7993	2830	5259	3529
		9610		8220	3200	7180	2600	6904	2184
C - 20		7370	1860	4160	3150	8720	2060	6493	2884
		7480	2590	5520	3220	8680	2760	8522	2740
Avr.		8150	2590	5966	3190	8190	2470	7306	2607
		6560	2500	6640	2950	8510	3540	8624	2260
A - 30		6200	1710	6870	3350	7840	2400	5165	3398
		6370	1890	6530	3110	7130	3230	7382	2220
Avr.		6320	2033	6680	3140	7830	3060	7057	2626
		6780	2340	7000	2850	7910	2510	8429	1834
B - 30		6180	2300	6970	3590	9620	2530	4914	2672
		6120	2050	4510	3050	8530	3840	6149	3268
Avr.		6360	2230	6160	3160	8690	3250	6497	2591
		5820	1550	5610	3220	9470	3770	7442	2039
C - 30		5360	1940	7800	3220	9450	2450	8746	2857
		5860	1250	7730	2930	7840	3490	8063	2144
Avr.		5640	1580	7050	3120	8920	3240	8083	2347
			1640	4770	2270	9950	1750	4516	2032
A - 40		4800	1560	5320	2970	4720	2840	4812	2975
		6540	2320	6700	3120	5010	2980	6369	2680
Avr.		5670	1840	5600	2790	6560	2520	5232	2562
		7070	1900	4840	1900	6960	2930	5843	1204
B - 40		5529	1760	7360	2090	7380	2270	4458	1870
		6120	2040	1370	2260	6750	2040	7418	2960
Avr.		6280	1900	6520	2080	7030	2410	5906	2011
		4710	1030	7700	2500	8710	2320	5828	2047
C - 40		5470	1820	6360	2930	7340	2010	5240	1428
		6110	1560	6490	1870	6820	2040	6380	2282
Avr.		5450	1470	6850	2433	7620	2040	5816	1919
Average of Averages									
A, B & C		6033	3634	7853	4510	7300	4320	8309	4050
A-10, B-10, C-10		5913	2993	8509	3690	7690	4020	6252	3876
A-20, B-20, C-20		7310	2868	6800	3540	7700	2970	6887	3401
A-30, B-30, C-30		6100	1944	6630	3140	8480	3180	7212	2521
A-40, B-40, C-40		5793	1737	6320	2101	7070	2320	5651	2164
Average of Highest Breaks									
A, B, & C		6937	3890	9590	4790	8920	4910	8869	4703
A_{10}, B_{10} & C_{10}		6567	3260	9500	4570	8080	4550	6691	4435
A_{20}, B_{20} & C_{20}		8550	3150	8500	4660	8730	3310	7958	3641
A_{30}, B_{30} & C_{30}		6400	2260	7220	3390	9200	3720	8600	3174
A_{40}, B_{40} & C_{40}		6573	2060	7260	2770	8540	2740	6722	2506

RESULTS OF COMPRESSION TESTS

(Neat Specimens)

Tested at age of 28 days

Series No.	Spec'c made 1916 Date	Dim'nsions				Weight		Load		Stress	
		Height Inches	Diam. Inches	Area in Sq. in.	Vol. in Cu. In.	Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult. lb./sq. in
		1.95	2.00	3.14	6.12	221	36.14	16500	17210	5260	5480
A	1-29	1.98	2.00	3.14	6.22	221	35.54	17470	22640	5560	7220
		2.00	2.00	3.14	6.28	231	36.79	12700	18400	4040	5800
Avr.								15557	19417	4950	6170
		2.00	2.00	3.14	6.28	231.5	36.84	14830	16550	4730	5280
B	1-29	2.00	2.00	3.14	6.28	231.5	36.84	17820	21500	5780	6850
		2.00	2.00	3.14	6.28	232	36.98	13090	21930	4170	6980
Avr.								15247	19993	4890	6370
		1.96	2.00	3.14	6.28	225	35.84	11100	14270	3540	4550
C	1-29	2.00	1.98	5.08	6.16	238	38.64	20740	20740	6610	6610
		1.96	2.02	3.20	6.27	226	36.04	15670	17670	4900	5520
Avr.								15837	17560	5020	5560
		2.02	2.06	3.33	6.73	232	34.48	11100	21940	3330	6590
A - 10	1-31	2.08	2.07	3.36	6.99	232	33.20	10000	21600	2980	6430
		2.00	2.03	3.23	6.46	225	34.82	9100	14200	2820	4400
Avr.								10063	19247	3040	5810
		1.96	1.99	3.11	6.10	208	34.12	12860	19000	4130	6120
B - 10	2-2	1.97	1.97	3.05	6.02	211	35.06	7000	19600	2290	6450
		1.96	2.00	3.14	6.16	213	34.58	17500	20070	5760	6400
Avr.								12453	19553	4060	6320
		2.05	2.05	3.30	6.76	235	34.78	15000	18150	4550	5500
C - 10	1-31	2.03	2.05	3.30	6.70	236	35.26	12400	15370	3760	4660
		2.07	2.05	3.30	6.83	237	34.70	13000	21970	3940	6660
Avr.								13467	18497	4080	5610
		2.02	2.11	3.49	7.05	238	33.74	17500	21890	5020	6280
A - 20	2-2	2.02	2.07	3.36	6.79	237	34.91	14500	21710	4320	6470
		2.02	2.03	3.23	6.52	236	36.18	23000	26060	7130	8700
Avr.								18333	23220	5490	7150
		2.01	1.97	3.05	6.12	215	35.12	13850	19680	4540	6450
B - 20	2-3	2.02	1.96	3.01	6.08	214	35.20	14570	18420	4840	6130
		2.03	1.96	3.01	6.12	216	35.32	20380	22100	6770	7340
Avr.						215		16267	20067	5380	6640
		2.00	1.97	3.05	6.10	218	35.74		29280		9610
C - 20	2-16	2.00	2.02	3.20	6.40	232	36.28	16000	23570	5010	7370
		2.00	2.00	3.14	6.28	229	36.50	23460	23460	7480	7480
Avr.								18730	25437	6250	8150
		1.98	2.00	3.14	6.22	228	37.68	14000	20590	4460	6560
A - 30	2-16	2.00	2.00	3.14	6.28	230	36.63	12500	19430	3980	6200
		2.00	1.98	3.08	6.16	218	35.41	14000	19630	4550	6370
Avr.								13500	19883	4330	6320
		2.00	2.00	3.14	6.28	225	35.84	16800	21300	5350	6780
B - 30	2-16	2.00	2.00	3.14	6.28	227	36.18	13700	19400	4370	6180
		2.00	2.00	3.14	6.28	225	35.84	18700	19220	5960	6120
Avr.								16407	19977	5230	6360
		2.00	2.00	3.14	6.28	227	36.18	13500	18260	4310	5820
C - 30	2-17	2.01	1.98	3.08	6.16	221	35.90	14020	16500	4560	5360
		2.02	2.00	3.14	6.28	226	36 00	17620	18400	5620	5860
Avr.								15047	17720	4830	5640
		2.02	1.97	3.05	6.16	220	35.72				
A - 40	2-19	2.00	1.97	3.05	6.10	220	36.08	12940	14630	4240	4800
		2.00	2.02	3.20	6.40	229	35.81	20920	20920	6540	6540
Avr.								16930	17775	5390	5670
		2.01	1.99	3.11	6.25	219	35.05	21050	22000	6770	7070
B - 40	2-19	2.02	2.02	3.20	6.47	229	35.40	17640	17640	5520	5520
		2.00	2.02	3.20	6.40	227	35.30	19330	19530	6120	6120
Avr.								19407	19723	6130	6280
		2.03	2.02	3.20	6.50	232	35.70	15060	15060	4710	4710
C - 40	2-23	2.05	2.01	3.17	6.28	231	36.79	16900	17330	5330	5470
		2.02	1.99	3.11	6.28	221	35.20	17300	18990	5570	6110
Avr.								16420	17130	5200	5450
Average of Averages											
A - B - C										4953	6033
A_{10} - B_{10} - C_{10}										3727	5913
A_{20} - B_{20} - C_{20}										5700	7310
A_{30} - B_{30} - C_{30}										4797	6100
A_{40} - B_{40} - C_{40}										5573	5793
Average of highest breaks											
A - B - C										5983	6937
A_{10} - B_{10} - C_{10}										4547	6567
A_{20} - B_{20} - C_{20}										7127	8550
A_{30} - B_{30} - C_{30}										5343	6400
A_{40} - B_{40} - C_{40}										6293	6573

RESULTS OF COMPRESSION TESTS

(Neat Specimens)

Tested at age of 12 weeks

Series No.	Spec's made 1916 Date	Dimension				Weight		Load		Stress	
		Height Inches	Diam. Inches	Area in Sq. in.	Vol. in Cu. in.	Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult lb./sq. in
A	1-29	2.00	1.98	3.08	6.16	238	38.62	17200	19820	5580	6490
		2.01	2.00	3.14	6.31	238	37.7	17250	22150	5500	7060
		2.04	1.98	3.08	6.29	237	37.67	27240	27240	8860	8860
Avr.								20563	23070	6650	7470
B	1-29	2.00	1.97	3.05	6.10	234	38.38	31620	31620	10380	10380
		2.02	1.98	3.08	6.23	237	38.04	20080	25800	10530	8380
		2.00	1.97	3.05	6.10	236	38.7	12100	20410	3970	6700
Avr.								21267	25943	8293	8487
C	1-29	2.00	1.98	3.08	6.16	227	36.88	12810	2030	4160	6790
		1.98	1.96	3.01	5.96	224	37.61	13110	19540	4360	6500
		2.00	1.96	3.01	6.02	229	38.02	17870	28610	5940	9520
Avr.								14597	23020	4820	7603
A_{10}	1-31	2.04	2.02	3.20	6.53	234	35.85	15400	20000	4820	6250
		2.05	2.04	3.27	6.70	235	35.08	11300	22400	3460	6860
		2.00	2.00	3.14	6.28	219	34.88	12100	29820	3850	9520
Avr.								12933	24073	4040	7543
B_{10}	2-2	1.97	1.98	3.08	6.07	215	35.42	17460	33880	5670	11000
		1.98	1.96	3.01	5.96	215	36.08	23870	30010	7940	9980
		2.00	1.98	3.08	6.16	215	34.9	20010	33500	6500	10860
Avr								20447	32463	6700	10613
C_{10}	1-31	2.06	2.04	3.27	6.74	238	35.3	16710	26180	5220	7980
		2.06	2.04	3.27	6.74	239	35.47	6470	20250	1980	6200
		2.04	2.02	3.20	6.53	239	36.61	10640	25410	3330	7940
Avr.								11273	23927	3510	7373
A_{20}	2-2	2.06	2.03	3.23	6.66	236	35.43	15400	20000	4780	6200
		2.05	2.03	3.23	6.63	236	35.6	11300	22440	3500	6960
		2.06	2.04	3.27	6.74	238	35.3	12100	29820	3710	9070
Avr.								12933	24086	4000	7410
B_{20}	2-3	2.04	2.02	3.20	6.53	230	35.24	7680	15350	2400	4800
		2.03	1.99	3.11	6.32	216	34.17	19030	25540	6130	8210
		2.04	1.98	3.08	6.29	217	34.5	15260	24830	4950	8070
Avr.								13990	21907	4490	7026
C_{20}	2-16	2.01	1.98	3.08	6.19	222	35.88	14360	25340	4670	8220
		2.00	2.00	3.14	6.28	221	36.23	9800	13060	2960	4160
		1.99	1.99	3.11	6.20	219	35.34	14850	17140	4780	5520
Avr.								13003	18513	4140	5966
A_{30}	2-16	2.00	1.97	3.05	6.10	220	36.08	9160	20340	3000	6640
		2.00	1.98	3.08	6.16	219	35.57	10770	21150	3500	6870
		2.02	2.00	3.14	6.34	234	36.91	8430	20490	2680	6530
Avr.								9453	20620	3060	6680
B_{30}	2-16	2.02	2.00	3.14	6.34	227	35.8	16460	21980	5240	7000
		2.04	2.01	3.17	6.47	228	35.23	15970	22080	5040	6970
		2.04	2.02	3.20	6.53	229	35.08	12100	14420	3780	4510
Avr.								14550	17790	4590	5600
C_{30}	2-17	2.01	1.96	3.01	6.05	219	36.21	18110	18110	5610	5610
		2.01	1.97	3.05	6.13	218	35.57	13550	23770	4440	7800
		2.09	2.02	3.20	6.69	237	35.43	24710	24710	7730	7730
Avr							35.43	18790	22196	5930	7050
A_{40}	2-19	2.00	2.03	3.23	6.46	233	35.88	8050	15370	2490	4770
		2.01	2.02	3.20	6.43	231	35.92	14630	17000	4580	5320
		2.01	2.00	3.14	6.31	227	35.98	21000	21000	6700	6700
Avr.								14550	17790	4590	5600
B_{40}	2-19	2.03	2.00	3.14	6.37	227	35.55	13430	15190	4280	4840
		2.03	2.02	3.20	6.50	228	35.08	23560	23560	7360	7360
		2.00	2.00	3.14	6.28	225	35.84	22080	23140	7030	7370
Avr.								19690	20630	6220	6520
C_{40}	2-23	2.03	1.99	3.11	6.32	223	35.28	23950	23950	7770	7700
		2.05	2.03	3.22	6.60	233	35. 3	18870	20490	5870	6360
		2.05	2.02	3.20	6.56	233	35.5	20750	20750	6490	6490
Avr.											
Average of Averages.											
		A - B - C								6587	7853
		A_{10} - B_{10} - C_{10}								4750	8509
		A_{10} - B_{10} - C_{10}								4210	6800
		A_{20} - B_{20} - C_{20}								4560	6630
		A_{30} - B_{30} - C_{30}								5830	6320
Average of Highest Breaks											
		A - B - C								8390	9590
		A_{30} - B_{30} - C_{30}								5990	9500
		A_{30} - B_{30} - C_{30}								5230	8500
		A_{40} - B_{40} - C_{40}								5490	7220
		A_{40} - B_{40} - C_{40}								7250	7260

RESULTS OF COMPRESSION TESTS

(Neat Specimens)

Tested at age of 24 weeks

Series No.	Spec'c made 1916 Date	Dim'nsions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult. lb./sq. in
A	1-29	2.04	2.02	3.20	6.53	237	36.30	17740	22190	5550	6930
		2.04	2.00	3.14	6.41	239	37.30	20220	34740	6450	11050
		2.03	2.01	3.17	6.44	239	37.12	18660	19360	5880	6110
Avr.								18873	25430	5960	8030
B	1-29	2.03	2.02	3.20	6.50	238	36.64	15490	20690	4840	6470
		2.02	2.02	3.20	6.47	234	36.18	8720	14190	2720	4440
		2.04	2.02	3.20	6.53	237	36.30	16820	22020	5260	6890
Avr.								13677	18967	4270	5930
C.	1-29	2.08	2.02	3.20	6.66	237	35.59	19830	25320	6200	1920
		2.08	2.02	3.20	6.66	226	33.92	25150	28240	7860	8830
		2.02	2.04	3.27	6.61	238	36.01	23050	23050	7050	7050
Avr.								22677	25537	7040	7930
A_{10}	1-31	2.08	2.02	3.20	6.66	236	35.45	11450	24870	3580	7780
		2.05	2.04	3.27	6.70	236	35.25	10110	28230	3090	8640
		2.01	2.01	3.17	6.37	220	34.52	23840	25570	7530	8060
Avr.								15133	26223	4730	8160
B_{10}	2-2	1.98	1.98	3.08	6.10	212	34.78	12560	22210	4080	7220
		2.01	2.00	3.14	6.31	215	34.08	17200	20480	5480	6520
		2.02	1.97	3.05	6.16	216	35.07	15030	21810	4930	7160
Avr.								14930	21500	4830	6970
C_{10}	1-31	2.06	2.04	3.27	6.78	237	34.97	25080	25140	7680	7690
		2.06	2.02	3.20	6.59	240	36.42	18530	24910	5800	7780
		2.06	2.03	3.25	6.65	240	36.10	19000	27030	5890	8380
Avr.								20870	25693	6460	7950
A_{20}	2-2	2.10	2.01	3.17	6.66	238	35.77	19330	22890	6100	7230
		2.00	2.02	3.20	6.69	240	35.90	10650	16510	3330	5170
		2.06	2.02	3.20	6.59	238	36.14	15590	26710	4870	8350
Avr.								15190	22037	4770	6920
B_{21}	2-3	2.05	2.04	3.27	6.70	232	34.63	19920	29810	6100	9120
		2.06	2.02	3.20	6.59	230	34.92	11470	22470	7030	7030
		2.03	2.00	3.14	6.37	217	34.08	11340	24606	3620	7830
Avr.								17910	25627	5580	7993
C_{20}	2-16	2.01	2.00	3.14	6.31	221	35.05	12620	22530	4020	7180
		2.00	2.04	3.27	6.54	234	35.77	16940	28430	5180	8720
		2.01	1.98	3.08	6.19	219	35.40	22490	26740	7300	8680
Avr.							35.40	17350	25900	5500	8190
A_{30}	2-16	2.00	2.00	3.14	6.28	219	34.88	23000	26690	7330	8510
		2.00	1.99	3.11	6.22	220	35.35	20890	24610	6720	7840
		2.04	2.02	3.20	6.53	232	35.51	5130	22800	1600	7130
Avr.								16340	24720	5220	7830
B_{30}	2-16	2.03	2.03	3.23	6.56	227	34.61	23840	25550	7380	7910
		2.02	2.02	2.20	6.47	228	35.25	30770	30770	9620	9620
		2.01	1.99	3.11	6.25	217	34.72	22080	26510	7110	8530
Avr.								25563	27603	8040	8690
C_{30}	2-17	2.00	2.04	3.27	6.54	232	35.48	30980	30980	9470	9470
		2.00	1.97	3.05	6.10	217	35.59	30870	30870	9450	4950
		2.00	1.98	3.08	6.16	220	35.72	21800	24130	7080	7840
Avr.								27885	28660	8670	8920
A_{40}	2-19	2.04	2.02	3.20	6.53	232	35.53	31840	31840	9950	9950
		2.08	1.98	3.08	6.25	217	34.74		14520		4720
		2.04	2.05	3.30	6.73	232	34.50	7580	16520	2290	5010
Avr.								19710	20960	6120	6560
B_{40}	2-19	2.02	1.99	3.11	6.28	219	34.88	19450	21610	6260	6960
		2.01	1.99	3.11	6.25	217	34.74	20340	22970	6530	7380
		2.02	2.00	3.14	6.35	217	34.20	15329	21180	4880	6750
Avr.								18370	21920	5890	7030
C_{40}	2-23	2.04	2.04	3.27	6.67	235	35.23	28450	28450	8710	8710
		2.01	2.00	3.14	6.32	223	35.30	23040	23040	7340	7340
		2.04	2.00	3.14	6.41	224	34.94	21720	21720	6820	6820
Avr.								24403	24403	7620	7620
Average of Averages											
A - B - C										5760	7300
A_{10} - B_{10} - C_{10}										5340	7690
A_{20} - B_{20} - C_{21}										5280	7700
A_{30} - B_{30} - C_{30}										7310	8480
A_{40} - B_{40} - C_{40}										6540	7070
Average of Highest Breaks											
A - B - C										6520	8920
A_{10} - B_{10} - C_{10}										6900	8080
A_{20} - B_{20} - C_{20}										6810	8720
A_{30} - B_{30} - C_{30}										8810	9200
A_{40} - A_{40} - C_{40}										8400	8540

RESULTS OF COMPRESSION TESTS

(Mortar Specimens)

Tested at age of 52 weeks

		Dimension				Weight		Load		Stress	
Series No.	Spec'c made 1916 Date	Diam. inches	Height inches	Area in Sq. in.	Vol. in Cu. in.	Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult. lb./sq. in
		2.04	1.98	3.08	6.28	230	36.62	16800	28300	5454	9188
A		1.99	1.98	3.08	6.15	226	36.86	17500	27550	5682	8845
Avr.								17150	27925	5568	9066
		2.00	2.00	3.14	6.28	239	38.05	21000	25070	6688	7984
B		2.00	2.00	3.14	6.28	238	37.89	16000	24800	5095	7898
		2.03	2.00	3.14	6.37	237	37.25	20000	28760	6369	9159
Avr.								19000	26210	6050	8347
		2.00	2.00	3.14	6.28	239	38.05	19800	21850	6306	6944
C		2.00	1.90	3.08	6.75	229	37.17	20800	25440	6753	8259
		2.00	2.00	3.14	6.28	240	38.21	11500	23040	3667	7337
Avr.								17333	23443	5574	7513
		2.00	2.00	3.14	6.28	236	37.58	5200	12070	1656	38441
A_{10}		2.01	2.00	3.14	6.31	237	37.56	7000	17620	2229	5611
		2.00	2.00	3.14	6.28	235	37.42	7100	16470	2261	5245
Avr.								6433	15386	2049	4900
		2.00	2.00	3.14	6.28	230	36.62	13020	25000	4146	7961
B_{10}		2.00	1.96	3.02	*.04	216	35.76	10500	24150	3476	7996
		2.00	1.97	3.05	6.10	217	35.57	12500	25360	4098	8314
Avr.								12340	24837	3907	8090
		2.05	2.01	3.17	6.50	240	36.92	17000	17800	5362	5615
C_{10}		2.05	2.05	3.30	6.77	241	35.59	13400	16885	4060	5117
		2.03	2.04	3.27	6.64	243	36.60	6400	21470	1954	6565
Avr.								12133	18718	3792	5766
		2.07	2.00	3.14	6.50	239	36.77	17500	25570	5573	8143
A_{20}		2.06	2.01	3.17	6.53	238	36.44	11000	23010	3470	7258
		2.00	2.00	3.14	6.28	221	35.19	16420	27910	5229	8888
Avr.								14973	25496	4757	8096
		2.06	2.04	3.27	6.74	233	34.57	13000	21150	3975	6464
B_{20}		2.04	2.03	3.24	6.61	232	35.09	11000	16740	3395	5166
		2.00	2.00	3.14	6.28	220	35.03	9200	13030	2929	4149
Avr.								11067	16973	3433	5259
		1.98	2.00	3.14	6.22	220	35.38	17200	21680	5477	6904
C_{20}		2.00	2.00	3.14	6.28	235	37.40	13800	20390	3494	6493
		2.00	2.00	3.14	6.28	200	31.80	26760	26760	8522	8522
Avr.								19253	22943	5831	7306
		2.04	2.00	3.14	6.41	235	36.65	17000	27090	5414	8624
A_{30}		2.04	2.00	3.14	6.41	234	36.48	5200	16220	1656	5665
		2.00	2.00	3.14	6.28	232	36.95	15070	23180	4799	7382
Avr.								12423	22163	3956	7057
		2.00	2.00	3.14	6.28	229	36.48	22000	26470	7006	8429
B_{30}		2.00	2.00	3.14	6.28	232	36.96	9500	15440	3025	4914
		2.00	2.00	3.14	6.28	219	34.90	17100	19310	5445	6149
Avr.								16200	20406	5159	6497
		2.00	2.00	3.14	6.28	224	35.64	23370	23370	7442	7442
C_{30}		2.05	2.04	3.27	6.70	240	35.80	27500	28600	8409	8746
		2.04	2.00	3.14	6.41	227	35.40	19200	25320	6114	8063
Avr.								20023	25763	7322	8083
		2.00	2.00	3.14	6.28	217	34.59	10000	14180	3184	4516
A_{40}		2.00	2.00	3.14	6.28	207	32.97	12000	15110	3821	4812
		2.00	2.00	3.14	6.28	232	36.95	18000	20000	5732	6369
Avr.								13333	16430	4245	5232
		2.01	1.98	3.08	6.19	222	35.87	18000	18000	5843	5843
B_{40}		2.00	2.00	3.14	6.28	220	35.00	12000	14000	3821	4458
		2.00	1.99	3.11	6.22	219	35.20	23070	23070	7418	7418
Avr.								17690	18357	5694	5906
		2.00	2.00	3.14	6.27	225	35.90	17000	18310	5412	5828
C_{40}		2.00	1.99	3.11	6.22	224	36.00	10100	16310	3246	5240
		2.00	1.98	3.08	6.16	224	36.36	15500	19670	5030	6380
Avr.								14200	18097	4563	5816
Average of Averages											
A - B & C										5731	8309
A_{10} - B_{10} & C_{10}										3249	6252
A_{20} - B_{20} & C_{20}										4674	6887
A_{30} - B_{30} & C_{30}										5479	7212
A_{40} - B_{40} & C_{40}										4834	5650
Average of highest breaks											
A - B & C										6374	8869
A_{10} - B_{10} & C_{10}										3923	6691
A_{20} - B_{20} & C_{20}										6023	7958
A_{30} - B_{30} & C_{30}										6943	8600
A_{40} - B_{40} & C_{40}										6187	6722

RESULTS OF COMPRESSION TESTS

(Mortar Specimens)

Tested at age of 28 days

Series No.	Spec'c made 1916 Date	Dim'nsions		Area in Sq. in.	Vol. in Cu. In.	Weight		Load		Stress	
		Height Inches	Diam. inches			Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult. lb./sq. in
		2.05	2.06	3.33	6.83	2.58	37.77	13060	13060	3920	3920
A	2-23	2.03	2.00	3.14	6.37	239	37.52	10560	10560	3360	3360
		2.02	1.99	3.11	6.28	244	38.86	11240	11240	3620	3620
Avr.								11620	11620	3633	3633
		2.06	2.02	3.20	6.59	252	38.21	10240	10240	3200	3200
B	2-23	2.10	2.02	3.20	6.72	256	38.10	10830	10830	3390	3390
		2.08	2.03	3.23	6.73	257	38.2	11970	11970	3700	3700
Avr.								11013	11013	3430	3430
		2.10	2.02	3.20	6.72	258	38.4	12990	12990	4060	4060
C	2-26	2.10	2.04	3.27	6.87	260	37.81	12540	12540	3920	3920
		2.09	2.01	3.17	6.62	254	38.38	11200	11200	3540	3540
Avr.								12243	12243	3840	3840
		2.08	2.00	3.14	6.53	240	36.76	9450	9450	3010	3010
A_{10}	2-26	2.10	2.02	3.20	6.72	256	38.1	10960	10960	3420	3420
		2.09	2.02	3.20	6.68	254	38.04	11400	11400	3560	3560
Avr.								10603	10603	3330	3330
		2.05	2.00	3.14	6.44	235	36.5	7000	8500	2220	2700
B_{10}	2-26	2.04	1.99	3.11	6.35	233	36.7	9020	9020	2900	2900
		2.05	2.04	3.27	6.70	247	36.88	9400	9400	2870	2870
Avr.								8473	8773	2663	2823
		2.10	2.02	3.20	6.72	251	37.38	8520	8520	2660	2660
C_{10}	2-26	2.07	1.98	3.08	6.38	239	37.47	10210	10210	3320	3320
		2.06	1.98	3.08	6.35	251	39.52	7710	7710	2500	2500
Avr.								8813	8813	2827	2827
		2.05	2.00	3.14	6.44	246	38.2	11000	12010	3500	3830
A_{20}	2-28	2.04	1.97	3.05	6.23	242	38.86	9000	9000	2950	2950
		2.05	1.98	3.08	6.32	243	38.46	8690	8690	2850	2850
Avr.								9563	9900	3100	3210
		2.10	2.01	3.17	6.65	252	37.9	9650	9650	3040	3040
B_{20}	2-28	2.07	2.03	3.28	6.69	252	37.66	8900	8900	2750	2750
		2.07	1.97	3.05	6.32	237	37.5	8000	8000	2620	2620
Avr.								8850	8850	2803	2803
		2.06	2.03	3.23	6.66	249	37.39				
C_{20}	2-28	2.06	1.98	3.08	6.35	241	37.98	5740	5740	1860	1860
		2.05	2.03	3.23	6.62	236	35.64	5720	8380	1770	2590
Avr.								5720	8380	1770	2590
		2.09	1.98	3.08	6.44	236	36.62	7710	7710	2500	2500
A_{30}	3-1	2.09	2.03	3.23	6.75	254	37.65	5520	5520	1710	1710
		2.10	2.10	3.45	7.27	243	33.42	6550	6550	1890	1890
Avr.								6593	6593	2033	2033.
		2.10	1.98	3.08	6.47	241	37.28	7230	7230	2340	2340
B_{30}	3-1	2.10	2.00	3.14	6.60	251	38.04	7220	7220	2300	2300
		2.12	2.02	3.20	6.78	254	37.48	6560	6560	2050	2060
Avr.								7003	7003	2230	2230
		2.10	2.02	3.20	6.72	254	37.78	4950	4950	1550	1550
C_{30}	3-1	2.08	1.99	3.11	6.47	237	36.62	6030	6030	1940	1940
		2.12	2.00	3.14	6.65	254	38.18	3930	3930	1250	1250
Avr.								4970	4970	1580	1580
		2.08	1.99	3.11	6.47	240	37.10	5090	5090	1640	1640
A_{40}	3-3	2.06	1.97	3.05	6.29	236	37.56	4760	4760	1560	1560
		2.12	2.02	3.20	6.78	252	37.16	7420	7420	2320	2320
Avr.								5760	5760	1840	1840
		2.06	2.02	3.20	6.59	251	38.1	6100	6100	1900	1900
D_{40}	3-3	2.04	2.00	3.14	6.41	237	36.98	5520	5520	1760	1760
		2.06	2.02	3.20	6.59	248	37.62	6550	6550	2040	2040
Avr.								6057	6057	1900	1900
		2.08	2.02	3.20	6.66	247	37.1	3300	3300	1030	1030
C_{40}	3-3	2.08	2.03	3.23	6.73	250	37.16	5870	5870	1820	1820
		2.05	1.98	3.08	6.32	234	37.02	4820	4820	1560	1560
Avr.								4663	4663	1470	1470
Average of Averages											
A - B - C										3634	3634
A_{10} - B_{10} - C_{10}										2940	2993
A_{20} - B_{20} - C_{20}										2558	2868
A_{30} - B_{30} - C_{30}										1944	1944
A_{40} - B_{40} - C_{40}										1737	1737
Average of Highest Breaks											
A - B - C										3890	3890
A_{10} - B_{10} - C_{10}										3260	3260
A_{20} - B_{20} - C_{20}										2770	3150
A_{30} - B_{30} - C_{30}										2260	2260
A_{40} - B_{40} - C_{40}										2060	2060

RESULTS OF COMPRESSION TESTS

(Mortar Specimens)

Tested at age of 12 weeks

Series No.	Spec'c made 1916 Date	Dim'nsions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult. lb./sq. in
A	2-23	2.10	2.05	3.30	6.93	257	37.10	17220	17220	5220	5220
		2.08	1.95	2.98	6.20	237	38.23	13510	13510	4540	4540
		2.11	2.02	3.20	6.75	256	37.92	16540	16540	5170	5170
Avr.								15757	15757	4980	4980
B	2-23	2.07	2.02	3.20	6.62	254	38.37	12080	12080	3780	3780
		2.10	2.01	3.17	6.66	251	37.70	12810	12810	4040	4040
		2.10	2.04	3.27	6.87	258	37.56	10600	10600	3380	3380
Avr.								11830	11830	3730	3730
C	2-26	2.08	1.98	3.11	6.47	247	38.19	14690	14690	4720	4720
		2.10	2.02	3.20	6.72	255	37.94	14980	14980	4680	4680
		2.13	2.00	3.14	6.68	262	39.23	16000	16000	5100	5100
Avr.								15223	15223	4830	4830
A_{10}	2-26	2.02	2.01	3.17	6.41	240	37.44	8190	8190	2580	2580
		2.03	2.00	3.14	6.38	239	37.46	14560	14560	4630	4630
		2.02	1.98	3.08	6.28	235	37.42	11460	11460	3720	3720
Avr.								11400	11400	3640	3640
B_{10}	2-26	2.04	2.04	3.27	6.67	247	37.06	11730	11730	3590	3590
		2.02	1.97	3.05	6.16	236	38.30	15420	15420	5070	5070
		2.03	2.04	3.27	6.64	247	37.23	12070	12070	3690	3640
Avr.								13073	13073	4120	4120
	2-26	2.11	2.02	3.20	6.75	254	37.83	12810	12810	4010	4010
		2.10	2.02	3.20	6.72	253	37.64	8690	8690	2710	2710
		2.10	2.02	3.20	6.72	252	37.51	10310	10310	3230	3220
Avr.							37.51	10603	10603	3310	3310
A_{20}	2-28	2.09	1.99	3.11	6.50	242	37.22	13300	13300	4280	4280
		2.08	1.99	3.11	6.47	242	37.41	11640	11640	3740	3740
Avr.								12897	12897	4110	4110
B_{20}	2-28	2.10	2.03	3.23	6.78	258	38.08	10740	10740	3330	3330
		2.07	1.98	3.08	6.38	237	37.16	10560	10560	3430	3430
		2.10	2.02	3.20	6.72	255	37.64	10310	10310	3220	3220
Avr.								10537	10537	3330	3330
C_{20}	2-28	2.05	2.00	3.14	6.44	238	36.96	10030	10030	3200	3200
		2.10	2.02	3.20	6.72	253	37.64	10080	10080	3150	3150
		2.06	1.98	3.08	6.35	240	37.80	9920	9920	3220	3220
Avr.								10010	10010	3190	3190
A_{30}	3-1	2.08	2.00	3.14	6.53	240	36.77	9270	9270	2950	2950
		2.12	2.04	3.27	6.93	255	36.82	10930	10930	3350	3350
		2.04	2.00	3.14	6.41	256	39.94	9780	9780	3110	3110
Avr.								9993	9993	3140	3140
B_{30}	3-1	2.10	2.00	3.14	6.60	252	38.17	8960	8960	2850	2850
		2.08	1.99	3.11	6.47	241	37.26	11180	11180	3590	3590
		2.08	1.99	3.11	6.47	240	37.08	9490	9490	3050	3050
Avr.								9877	9877	3160	3160
C_{30}	3-1	2.08	1.98	3.08	6.41	236	36.82	9920	9920	3220	3220
		2.07	1.98	3.08	6.38	239	37.46	9930	9930	3220	3220
		2.10	2.02	3.20	6.72	254	37.79	9370	9370	2930	2930
Avr.								9740	9740	3120	3120
A_{40}	3-3	2.10	1.98	3.08	6.47	237	36.64	6990	6990	2270	2270
		2.10	2.02	3.20	6.72	249	37.04	9500	9500	2970	2970
		2.10	2.00	3.14	6.60	248	37.58	9820	9820	3120	3120
Avr.								8770	8770	2790	2790
B_{40}	3-3	2.10	2.00	3.14	6.60	240	36.38	5960	5960	1900	1900
		2.08	2.00	3.14	6.53	243	37.23	6560	6560	2090	2090
		2.08	2.00	3.14	6.53	241	36.92	7110	7110	2260	2260
Avr.								6543	6543	2080	2080
C_{40}	3-3	2.10	2.00	3.14	6.60	237	35.98	7870	7870	2500	2500
		2.05	1.98	3.08	6.32	236	37.39	9040	9040	2930	2930
		2.05	1.98	3.08	6.32	232	36.70	5770	5770	1870	1870
Avr.								7560	7560	2433	2433
Average of Averages											
A - B - C										4510	4510
A_{10} - B_{10} - C_{10}										3690	3690
A_{20} - B_{20} - C_{20}										3540	3540
A_{30} - B_{30} - C_{30}										3140	3140
A_{40} - B_{40} - C_{40}										2101	2101
Average of Highest Breaks											
A - B - C										4790	4790
A_{10} - B_{10} - C_{10}										4570	4570
A_{20} - B_{20} - C_{20}										3660	3660
A_{30} - B_{30} - C_{30}										3390	3390
A_{40} - B_{40} - C_{40}										2770	2770

RESULTS OF COMPRESSION TESTS

Tested at age of 24 weeks

(Mortar Specimens)

Series No.	Spec'c made 1916 Date	Dim'nsions				Weight		Load		Stress	
		Height inches	Diam. inches	Area in Sq. in.	Vol. in Cu. In.	Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in	Ult. lb./sq. in
		2.11	2.01	3.17	6.69	258	38.57	13730	15890	4330	5020
A	2-23	2.08	2.04	3.27	6.80	257	37.83	10290	11060	3150	3380
		2.12	2.01	3.17	6.72	259	38.52		12710		4020
Avr.								12010	13220	3740	4140
		2.12	2.03	3.23	6.85	254	37.08	13480	13480	4180	4180
B	2-23	2.10	2.04	3.27	6.87	252	36.66		17280		5500
		2.08	1.97	3.05	6.35	249	29.22	11280	11770	3700	3860
Avr.								13480	15380	4180	4840
		2.11	2.00	3.14	6.63	247	37.24	13180	13180	4200	4200
C	2-26	2.09	2.00	3.14	6.57	244	37.16	11150	11150	3550	3550
		2.11	2.02	3.20	6.75	256	37.94		13490		4220
Avr.								12165	12607	3870	3990
		2.06	1.98	3.08	6.35	236	37.20	12370	12370	4020	4020
A_{10}	2-26	2.12	2.02	3.20	6.78	255	37.60	14410	14410	4510	4510
		2.12	2.03	3.23	6.85	256	37.39	14630	14630	4530	4530
Avr.								13803	13803	4350	4350
		2.10	2.00	3.14	6.60	245	37.10	14000	14000	4460	4460
B_{10}	2-26	2.07	2.05	3.30	6.83	249	36.48	9390	9390	2840	2840
		2.06	2.05	3.30	6.80	246	36.18	14010	14010	4250	4250
Avr.								12467	12467	3850	3850
Avr.		2.10	2.03	3.23	6.78	262	37.14	8340	8340	2580	2580
C_{10}	2-26	2.11	2.04	3.27	6.90	252	36.52	15230	15230	4660	4660
		2.10	1.99	3.11	6.54	241	36.87	13380	13380	4310	4310
Avr.								12317	12317	3850	3850
		2.11	2.05	3.30	6.96	257	36.94	13660	13660	4140	4140
A_{20}	2-28	2.07	2.00	3.14	6.50	242	37.24	12160	12160	3870	3870
		2.10	2.00	3.14	6.60	242	36.70	8310	8750	2640	2780
Avr.								11377	11523	3550	3690
		2.09	2.00	3.14	6.57	240	36.53	9080	9080	2890	2890
B_{20}	2-28	2.12	2.02	3.20	6.78	253	37.30	7810	8170	2440	2550
		2.11	2.05	3.30	6.96	255	36.66	10020	10020	3040	3040
Avr.								8970	9090	2790	2830
		2.08	1.99	3.11	6.48	237	36.58	8100	8100	2600	2600
C_{20}	2-28	2.07	1.99	3.11	6.45	238	36.90	4200	6410	1350	2060
		2.08	2.05	3.30	6.87	252	36.66	9120	9120	2760	2760
Avr.								7140	7877	2240	2470
		2.08	2.05	3.30	6.87	255	37.12	10530	11690	3190	3540
A_{30}	3-1	2.07	2.02	3.20	6.63	242	36.50	6560	7700	2040	2400
		2.10	2.04	3.27	6.87	256	37.30	10540	10540	3230	3230
Avr.								9210	9977	2820	3060
		2.00	1.99	3.11	6.22	216	34.72	5650	7820	1820	2510
B_{30}	3-1	2.11	2.02	3.20	6.75	251	37.20	8090	8090	2590	2530
		2.12	2.04	3.27	6.93	253	36.52	12560	12560	3840	3840
Avr.								10325	10325	3250	3250
		2.11	2.02	3.20	6.75	254	37.66	12070	12070	3770	3770
C_{30}	3-1	2.09	1.97	3.05	6.38	237	37.14	6380	7500	2090	2450
		2.10	2.00	3.14	6.60	248	37.58	10690	10690	3490	3490
Avr.								9713	10087	3120	3240
		2.12	2.01	3.17	6.72	244	36.32	5260	5560	1660	1750
A_{40}	3-3	2.09	2.00	3.14	6.57	235	35.77	8910	8910	2840	2840
		2.11	2.04	3.27	6.90	252	36.52	9750	9750	2980	2980
Avr.								7973	8073	2490	2520
		2.13	2.00	3.14	6.69	242	36.18	9220	9220	2930	2930
B_{40}	313	2.14	2.04	3.27	6.72	255	37.96	7430	7430	2270	2270
		2.14	2.00	3.14	6.72	242	36.00	6420	6420	2040	2040
Avr.								7690	7690	2410	2410
		2.14	2.03	3.23	6.92	255	36.88	7500	7500	2320	2320
C_{40}	3-3	2.11	2.04	3.27	6.90	251	36.40	6570	6570	2010	2010
		2.12	2.04	3.27	6.93	254	36.66	6660	6660	2040	2040
Avr.								6660	6660	2040	2040
Average of Averages											
A - B - C										3930	4320
A_{10} - B_{10} - C_{10}										4020	4020
A_{20} - B_{20} - C_{20}										2860	2970
A_{30} - B_{30} - C_{30}										3060	3180
A_{40} - B_{40} - C_{40}										2310	2320
Average of Highest Breaks											
A - B - C										4240	4910
A_{10} - B_{10} - C_{10}										4550	4550
A_{20} - B_{20} - C_{20}										3310	3310
A_{30} - B_{30} - C_{30}										3610	3720
A_{40} - B_{40} - C_{40}										2270	2740

RESULTS OF COMPRESSION TESTS

(Mortar Specimens)

Tested at age of 52 weeks

Series No.	Spec'c made Date	Dim'nsions				Weight		Load		Stress	
		Height inches	Diam. inches	Area in inches	Vol. in inches	Total Gms.	Unit Gms.	1st Cr. lbs.	Ult. lbs.	1st Cr. lb./sq. in.	Ult. lb./sq. in.
		2.05	2.05	3.30	6.77	258	38.1	12570	12570	3809	3809
A		2.05	2.00	3.14	6.44	241	37.4	10380	10380	3304	3304
		2.07	2.00	3.14	6.50	260	40.0	15890	15890	5056	5056
Avr.								12946	12946	4058	4056
		2.05	2.00	3.14	6.44	244	37.9	12110	12110	3859	3859
B		2.04	2.00	3.14	6.41	238	37.1	11000	13000	3502	4140
		2.03	2.00	3.14	6.37	237	37.2	8000	10210	2547	3252
Avr.								10370	11773	3303	3750
		2.04	2.00	3.14	6.41	246	38.4	12000	13650	3822	4350
C		2.04	2.00	3.14	6.41	245	38.2	10000	11850	3180	3772
		2.02	2.02	3.21	6.48	248	38.3	15000	15770	4672	4912
Avr.								12333	13757	4225	4345
		2.00	2.00	3.14	6.28	257	40.9	11500	11890	3660	3782
A_{10}		2.04	2.00	3 14	6.41	239	37.3	11550	11550	3678	3679
		2.00	2.00	3.14	6.28	260	41.4	12000	12000	3821	3820
Avr.								11683	11813	3720	3760
		2.08	2.00	3.14	6.53	246	37.7	13000	13600	4138	4331
B_{10}		2.05	2.02	3.21	6 58	248	37.7	10600	16080	3300	3327
		2.00	1.93	2.93	5.86	238	40.7	14500	14500	4950	4948
Avr.								12700	12927	4129	4202
		2.10	2.00	3.14	6.59	256	38.9	9506	9500	3240	3025
C_{10}		2.06	2.00	3.14	6.47	256	39.6	14200	14250	4540	4537
		2.05	2.00	3.14	6.43	242	37.6	10800	10800	3440	3440
Avr.								11500	11517	3740	3667
		2.12	2.00	3.14	6.66	256	38.4	8000	11970	2548	3812
A_{20}		2.12	2.00	3.14	6.66	255	38.3	12860	12860	4068	4069
		2.04	2.04	3.27	6.67	259	38.8	13000	14120	3976	4320
Avr.								11287	12983	3531	4067
		2.05	2.00	3.14	6.43	254	39.5	8000	9940	2547	3166
B_{20}		2.04	2.00	3.14	6.40	252	39.4	11500	11680	3661	3720
		2.05	2.00	3.14	6.43	255	39.7	11610	11610	3700	3700
Avr.								10370	11077	3303	3529
		2.08	2.00	3.14	6.53	244	37.4	6200	6860	1973	2184
C_{20}		2.05	2.02	3.21	6.58	257	39.1	9000	9260	2810	2884
		2.02	2.02	3.21	6.48	255	39.3	8500	8800	2647	2740
Avr.								7900	8307	2477	2607
		2.10	2.00	3.14	6.59	257	39.0	7000	7100	2228	2260
A_{30}		2.04	1.98	3.08	6.28	239	38.1	10100	10470	3279	3398
		2.07	2.04	3.27	6.77	258	38.1	7260	7260	2220	2220
Avr.								8120	8277	2576	2626
		2.07	2.00	3.14	6.50	244	37.6	5500	5760	1751	1834
B_{30}		2.07	2.04	3.27	6.77	257	38.0	8740	8740	2673	2672
		2.06	2.00	3.14	6.47	244	37.7	10260	10260	3268	3268
Avr.								8166	8253	2564	2591
		2.06	2.00	3.14	6.47	256	39.6	6400	6400	2039	2039
C_{30}		2.04	2.00	3.14	6.41	252	39.3	8470	8970	2857	2857
		2.05	2.00	3.14	6.43	251	39.1	6740	6740	2130	2144
Avr.								7203	7370	2345	2347
		2.05	1.98	3.08	6.31	239	37.9	6120	6260	1987	2032
A_{40}		2.10	2.00	3.14	6.59	253	38.4	9290	9340	2957	2975
		2.08	2.00	3.14	6.53	240	36.8	8425	8425	2681	2680
Avr.								7945	8008	2542	2562
		2.10	2.00	3.14	6.59	252	38.2	5980	5980	1904	1904
D_{40}		2.10	2.00	3.14	6.59	246	37.4	5870	5870	1870	1870
		2.10	2.00	3.14	6.59	252	38.2	7000	7100	2230	2260
Avr.								6283	6317	2001	2011
		2.08	2.00	3.14	6.53	251	38.5	6000	6430	1910	2047
C_{40}		2.10	2.00	3.14	6.59	249	37.8	4480	4480	1428	1428
		2.11	2.00	3.14	6.62	250	37.8	7170	7170	2282	2282
Avr.								5883	6027	1873	1919
Average of Averages											
A - B & C										3860	4050
A_{10} - B_{10} & C_{10}										3863	3876
A_{20} - B_{20} & C_{20}										3104	3401
A_{30} - B_{30} & C_{30}										2495	2521
A_{40} - B_{40} & C_{40}										2139	2164
Average of Highest Breaks											
A - B & C										4529	4703
A_{10} - B_{10} & C_{10}										4468	4435
A_{20} - B_{20} & C_{20}										3526	3641
A_{30} - B_{30} & C_{30}										9404	3174
A_{40} - B_{40} & C_{40}										2490	2506

TIME OF SET AND NORMAL CONSISTENCY

	Time of Set By Vicat.				N'rm'l C'nsistency	
	Initial		Final			
	Hours	Minutes	Hours	Minutes	Neat paste Per Cent	1:3 Sand Mortar Per Cent
A	2	50	5	20	22	10.2
A_{10}	0	20	5	10	26	10.8
A_{20}	1	35	5	30	23	10.3
A_{30}	4	40	8	30	22½	10.25
A_{40}	5	03	6	23	21½	10.1
B	4	55	9	00	21	10.1
B_{10}	3	15	6	20	24	10.5
B_{20}	2	15	5	50	22½	10.25
B_{30}	5	45	9	35	22	10.2
B_{40}	7	35	10	15	21	9.9
C	3	50	5	55	21½	10.1
C_{10}	3	45	6	—	25	10.7
C_{20}	4	35	8	10	23½	10.4
C_{30}	5	02	7	25	22½	10.25
C_{40}	4	55	7	25	21½	10.1
			Averages			
A, B, C	3	52	6	45	21½	10.13
A_{10}, B_{10}, C_{10}	2	27	5	50	25	10.66
A_{20}, B_{20}, C_{20}	2	48	6	30	23	10.32
A_{30}, B_{30}, C_{30}	5	09	8	30	22⅛	10.23
A_{40}, B_{40}, C_{40}	5	51	8	01	21⅛	10.03

SIEVE ANALYSIS

Cement Series No.	Percentages						
	Passing No. 200	Retained on No. 200	Retained on No. 150	Retained on No. 100	Retained on No. 65	Retained on No. 48	Retained on No. 35
A	78.0	22.0	15.3	5.6	0.7	0.1	0.0
B	78.2	21.8	15.9	6.1	0.75	0.0	0.0
C	77.3	22.7	16.4	4.6	0.8	0.3	0.1
Sand	17.9	82.1	55.9	16.4	5.1	1.8	0.6

MISSOURI SCHOOL OF MINES
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Volume Three **Number Four**

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

BULLETIN

MAY, 1917

TECHNICAL SERIES

STUDIES IN THE PRODUCTION OF OILS AND TARS FROM BITUMINOUS MATERIALS

ROLLA, MO.

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SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

STUDIES IN THE PRODUCTION OF OILS AND TARS FROM BITUMINOUS MATERIALS

BY

JOHN CHARAVELLE INGRAM, M. S.,

Assistant Professor of Chemistry

ROLLA, MO.
1917

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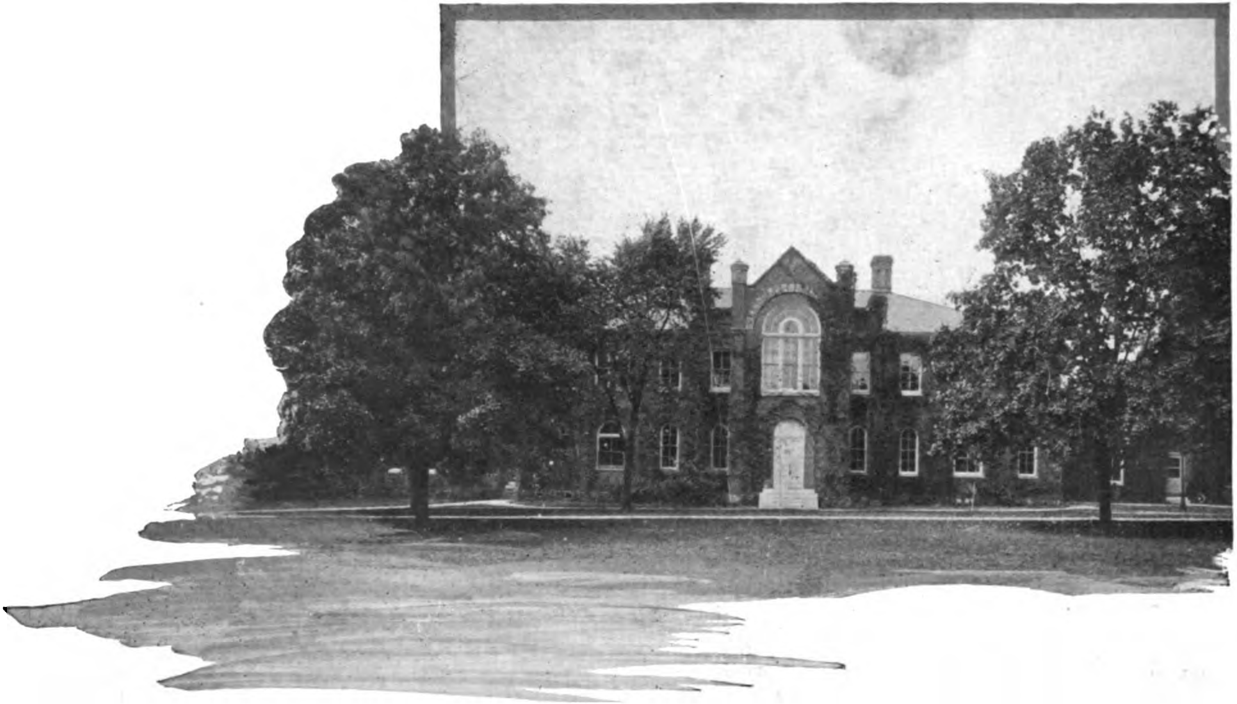

CHEMISTRY BUILDING

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STUDIES ON THE PRODUCTION OF OILS AND TARS FROM BITUMINOUS MATERIALS

INTRODUCTORY NOTE

It has long been known that the various bituminous materials when subjected to destructive distillation will yield hydrocarbon mixtures which are classified as "tars" or oils. Although no distinct line can be drawn between these two types, it is generally admitted that tars are heavier than water and contain "free carbon" while the oils do not contain this constituent in appreciable quantity and have a gravity of less than one.

There is little probability that any of the hydrocarbons in the condensate are present in the material before distillation, it being generally accepted that the tar and oil result from the pyro-decomposition or "cracking" of the kerogens[1]. Mr. Lewis T. Wright[2] has shown that the chemical nature of the products obtained depends primarily upon the temperature employed and numerous other investigators[3] have called attention to the effect of the size, shape and position of the retort, rate of heating, velocity and dilution of the gases and addition of catalytes. A comparison of the tar produced by the two commercial processes of coal carbonization, the by-product oven (vertical) and the ordinary gas retort (horizontal) will show the importance of these physical factors.

It is certain that the nature of the bituminous material employed exercises the greatest influence upon the products, although certain variations in the chemical make-up of the tars can be attributed to the process used. Before the advent of petroleum, vegetable and animal matter and their fossil remains constituted the only practical source of hydrocarbons, and today many such substances are subjected to destructive distillation on a commercial scale. The following table prepared from the sources indicated will give some idea of the hydrocarbons obtained from the various carbonaceous materials by processes in operation to-day.

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[1] Kerogens—"A term applied to the bituminous materials in Scottish Oil Shale." Bacon and Hamor—American Petroleum Industry, Vol 2, p. 877.

[2] Jour. of Gas Lighting, Vol. 52, p. 169.

[3] Warnes—Coal Tar Distillation, p. 1.
Wagner, Coal Gas Residuals, p. 8.
Lang—By-prod. of Coal Gas Manufacture, pp. 34-35.

DISTILLATION PRODUCTS OF BITUMINOUS MATERIALS

Material	Industrial Products	Chief Hydrocarbon Constituent
Wood[4]	Charcoal, methyl alcohol, acetic acid, acetone, creosotes, gas.	Paraffinoids Oxygenated Bodies, Cresols.
Peat[5]	Semi-charcoal, acetic acid, ammonium salts, methyl alcohol, creosotes, paraffines.	
Lignite[6] (Braunkohle)	Briquetting "Breeze", Paraffine base oils, cresols, gas, ammonia.	Paraffines, Olefines, Alcohols, Esters.
Cannel Coal[7]	Semi-coke (of little value) paraffine, base oil, cresols, ammonia gas.	Paraffines, Olefines. Polycyclic compounds.
Bituminous Shale[8]	Paraffine, base oil, cresols, ammonia.	Paraffines, Olefines. Polycyclic compounds.
Bituminous Coal[9]	Coke, coal tar, ammonia, gas.	Benzol & Toluol Napthalene, Anthracene. Phenol & Anilin.
Ozocerite[10]	Paraffine, paraffine base oil and gas.	Paraffines, Olefines.
Bones[11]	Animal charcoal, "Dippel's" Oil, ammonia.	Paraffines, Olefines. Nitrogen compounds.

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[4] Rogers—Manual of Industrial Chemistry, Chap. 23.

[5] Nystrom—Peat and Lignite, Their Mfg. and Use in Europe. Canadian Dept. of Mines. Mines Branch 1908.

[6] Scheithaur—Shale Oils and Tars, p. 52.

[7] Gas Manufacture, W. J. A. Butterfield, p. 145. Lumaghi, Grotts and Ingram, Thesis, Mo. School of Mines and Metallurgy 1916.

[8] Groves and Thorp, Chemical Technology, vol. 2. Lighting, pp. 220-21.

[9] Lange, By-products of Coal Gas Mfg., pp. 34-35.

[10] Groves and Thorp, Chemical Technology, Vol. 2, Lighting, p. 204.

[11] Thorp, Outline of Industrial Chemistry, p. 311.

Upon examination of the literature dealing with the production of hydrocarbons by destructive distillation it was found that although a vast amount of data concerning wood, lignite, shale and bituminous coal was available, the amount of information regarding the products from cannel coal was very limited. In view of the apparent revival of interest in petroleum chemistry due in part to the ever increasing demand for motor fuel, coupled with the decline[12] in production of high gasoline petroleums, it was thought that a study of the oils obtained from some of the Mid-western cannel coals might furnish interesting information.

With this in view, an investigation[13] was undertaken in 1916, in the course of which a preliminary study of the distillation of these coals was made, and the design, erection and testing of the retorts and condensers used in the present research were accomplished.

HISTORICAL OUTLINE

In 1739 an English experimenter, John Clayton,[14] investigating the gases found in coal mines, noted the effects of heating coal in a closed retort and thus laid the foundation for what has been termed the first great chemical industry. Clegg, a pupil of John Watt, made possible the commercial utilization of illuminating gas by eliminating many of the technical difficulties, and thus it became possible to light a part of the City of London with gas in 1813. A British company was founded by Clegg which became later the Imperial Continental Gas Association to whose efforts are due the main developments in industries founded on destructive distillation. No references could be found which gave the first utilization of the by-products tar and ammonia but it is probable that the value of the paraffine oil content of the former was early recognized and this complex mixture worked up to supply material for the lubrication of Watt's newly invented engine.

[15] "As early as 1694, Eele, Hancock and Portlock made pitch tar and oyle from a kind of stone, and in 1781 the Earl of Dundonald obtained oil from coal by a process of distillation." Stimulated by[16] Von Reichenbach's discovery of paraffine which he isolated from wood tar in 1830, many investigators attempted to obtain this then valuable substance

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[12] Senate Document, No. 310.
[13] Grotts, Lumaghi and Ingram, Thesis, Mo. School of Mines and Metallurgy.
[14] Molinari, General and Industrial Chemistry—Organic, p. 36.
[15] Groves and Thorp, Chemical Technology, Vol. 2, Lighting, p. 212.
[16] Liebig's Annalen, 6, 202.

by distillation from the various bituminous materials available. Early in the thirties Laurent,[17] aided by Selligue and De la Haye produced oil and paraffine by treating a carbonaceous shale from Autun in Southern France. The several producers who have surmounted the economic obstacles are to-day producing under the name of the Societe Lyonnaise des Schistes Bitumineux du Bassin d'Autun. During the forties the oil-yielding material to receive the greatest amount of attention was peat. Distillation plants were erected in Ireland,[18] Germany and Austria, but in every case the production of tar or oil has become subordinate to that of coke.

We must turn again to England, or rather to Scotland, for an account of the greatest development of the oil industry prior to the discovery of petroleum in America. In 1848 James Young,[19] who has been called "the father of the oil industry," built a refinery for treating a species of "rock oil" obtained from a colliery at Alfreton. After the exhaustion of the supply of this material many specimens of English and Scottish coals were distilled with the view of determining their relative oil yields. Boghead[20] coal and Torbanehill[21] mineral were found most suitable and they were worked by several dry distillation processes until 1862 when this supply became depleted and the manufacturers had to resort to the working up of bituminous shale (oil shale), a material which yields a much smaller quantity of oil. By practicing the most rigid industrial economies in the utilization of all by-products the shale distillers have been able to compete with foreign petroleum derivatives and prior to the war were retorting several million tons per annum and recovering over one hundred million gallons of crude oil.[22] Seven companies were known to be in operation in Scotland in 1910.

Encouraged by reports of the success of the Scottish industry, several Saxon companies attempted the commercial distillation of lignite in the now classic "Braunkohle"

[17] Bulletin Canadian Dept. of Mines.

[18] Zeits. Angew. Chemie. p. 524. 1893.

[19] The Shale Oil Industry of Scotland, Econ. Geol., Vol. 3, No. 7, p. 575.

[20] Boghead Coal—Bacon and Hamor, American Petroleum Industry, Vol. 2, p. 855.

"A hightly bituminous Scottish mineral containing 60-70 percent of volatile matter, from which Young obtained 120-130 gallons of crude oil per Ton."

[21] Torbanehill mineral—*Ibid.*, p. 917.

[22] Baskerville and Hamor, Economic Possibilities of American Oil Shales. —E. & M. J., 1909, Vol. 88, No. 4, p. 150.

district of Central Germany. Grotowsky,[23] Schliephacke, B. Huebner and Riebeck are credited with the development of this first step in German coal tar practice. The history of this German "Braunkohle Industrie" is strikingly similar to that of the Scottish Shale Oil industry. After the initial troublous period had passed which is attendant upon all new enterprises, an era of uniform development took place. The disaster which threatened from the discovery and introduction of petroleum was avoided by strict attention to the working up of ammonia and retort residues and by the organization of the companies into a sort of protective association known as the Verein fur Mineraloelindustrie. From the latest information available it seems that the present tendency[24] in the Saxon-Thuringian district is toward the briquetting rather than the retorting of the lignite.

The Industry in America

In 1853 the United States Chemical Manufacturing Company[25] began making lubricating oil from coal tar in Massachusetts and in 1857 a company[26] produced kerosene oils from a New Brunswick coal. Boghead coal was imported from Scotland and distilled on the Atlantic sea board but this material was soon replaced by cannel coal from West Virginia and Kentucky. The development during the next three years was very rapid and in 1860 it is reported[27] that the lamp and lubricating oil was being supplied by at least fifty-five companies who were distilling various kinds of bituminous materials. Retorting plants were located in New York, Pennsylvania, Massachusetts, Virginia, Ohio and Kentucky. About 1861 an attempt[28] was made to obtain oil on a commercial scale from a cannel coal found along the Missouri River in Callaway County, Missouri, but was not successful, due in part to the economic conditions at that time. The discovery and production of "rock oil" in Pennsylvania in 1859 paralyzed the infant "coal oil" industry and the distillers saved themselves from financial ruin by converting their plants into petroleum refineries. A few later attempts[29] were made to utilize the low grade coals and bituminous shales but in no case was the oil considered the primary product.

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[23] Scheithaur, Shale Oils and Tars, p. 6.

[24] Scheithaur, Shale Oils and Tars, p. 169.

[25] Groves and Thorp, Chemical Technology, Vol. 2, Lighting, p. 213.

[26] Chandler, Jour, Soc. Chem. Ind., Vol. 19, p. 612.

[27] Baskerville and Hamor, Economic Possibilities of American Oil Shales. —E. & M. J., Vol. 88, No. 4, p. 151.

[28] Private communication, Davis, Fulton, Mo.

[29] Baskerville, 8th. International Congress of Applied Chemistry.

To sum up, the industries having for their object the production of oil from carbonaceous substances have been successful, at some time, in England, France, Germany and America, and their product competes to-day with petroleum in all of the above mentioned countries except the latter. It is merely a question of time until the cycle will have been completed in the United States and the ever rising price of petroleum derivatives makes possible the commercial distillation of waste coals.

It should be noted that the American "coal oil" industries endeavored to make only kerosene and lubricating oil, and that at that time the now valuable gasoline and motor spirit was a waste product. No investigation seems to have been carried out with a view toward developing this most important branch. Little attention was paid to by-products which might have contained valuable constituents.

OBJECTS

The objects of the present investigation were:

1. To study the effects of heating certain cannel coals of Missouri and Illinois.
2. To determine the comparative yields of oil, gas, ammonia and residue.
3. To investigate the composition of the oil from the standpoint of gasoline, kerosene, heavy oils, paraffine and pitch.
4. To compare the products obtained with those of bituminous coal distilled under the same conditions.
5. To examine the data secured for any evidence which might lead to a better understanding of the phenomena accompanying destructive distillation.

GEOLOGY OF CANNEL COAL DEPOSITS

In order to determine the possibility of their use on a commercial scale, some knowledge is necessary of the size and extent of the cannel coal deposits. Bulletins of the Geological Surveys of Missouri and the neighboring states of Illinois and Kentucky, which are noted for their coal production, have been studied for that purpose.

Missouri

The Missouri coal beds are located in the northern and western parts of the state. Several beds have shown remarkable persistency and have been traced across the northwestern part of the state from Kansas to Iowa[30]. These beds are located in the main body of the Pennsylvanian series. "A region occupying a broad band lying east of the main body of the Pennsylvanian and extending well up into the central Ozarks bears scattered over its surface isolated Coal Measures pockets of a unique character," says Hinds.[30] "Deposits of this character are known to occur in at least thirty-five counties, and it is probable that future geologic work will disclose many others. Pockets were formed in sink holes and in narrow valleys in Mississippian or older formations, and few are more than one acre in lateral extent. The coal they bear is predominantly cannel and in many places is remarkably thick, some deposits measuring more than fifty feet and one shaft having penetrated ninety feet of coal. Cannel is a compact massive coal with dull satiny lustre and smooth conchoidal fracture." An aggregate of 500,000 tons in a single pocket is exceptional; most of them are much smaller.

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[30] Hinds, Mo. Bur. Geol. and Mines, Vol. XI, p. 9, 10.

Deposits of this nature are divided into two classes.[31] (1). outliers from true coal measures, preserving regular order of arrangement of slates, clays, coals, etc., and (2) drifted deposits, including (a) drifted in unbroken masses and retaining, after being drifted, a regular succession of beds as in the first class; (b) drift in broken or communicated masses. These deposits are predominant in Lincoln. Montgomery, Callaway, Morgan, Benton, Pettis, Saline and Jasper Counties as follows:

20 feet drift.
8 to 10 feet sandy shale.
3 feet bituminous coal.
Cannel coal—unknown thickness.

In Howard County, thick layers of bituminous slates are reported. Moniteau County contains a number of coal pockets; one of these is reported to be 150x400 feet and the thickness of the cannel coal is said to be 45 feet.[32] At Versailles, in Morgan County, there are a number of small cannel deposits. Cannel coal was observed at five different locations in Miller County.[33] A bed of cannel coal three inches in thickness above the bituminous vein was observed in Lafayette County.[34]

Illinois

Over 36,000 square miles of the 55,000 square miles of the State of Illinois are underlain by coal beds.[35] Most of this coal is bituminous coal of varying quality. It is hard to form an estimate of the cannel coal deposits from the work of the Illinois Geological Survey. These perhaps have not been deemed of sufficient importance or of sufficient extent to warrant investigation. The only deposits mentioned are at two localities in Northern Illinois.[36] These are reported as found in elongated lenses up to a foot or more in thickness, perhaps 100 yards long on the average. These were seen most often above the rest of the coal, adding to the total thickness and not replacing the coal of the normal seam. The analyses averaged as follows: Water, 2.78%; Volatile, 41.26%; Fixed Carbon, 30.20%; Ash, 25.76%. No other reports of the existence of cannel are found in the recent bulletins of the Illinois Geological Survey. It is known (by private correspondence) that other deposits exist, but nothing is known as to their size and extent.

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[31] Geol Survey of Missouri, Vol. I.
[32] Mo. Bur. of Geol. & Mines, Vol. XI, pp. 307 and 318.
[33] Mo. Bur. of Geol. & Mines, Geol. of Miller Co., Vol. I.
[34] Mo. Bur. of Geol. & Mines, Iron & Coal, 1872.
[35] Illinois Coal Mining Investigations, Bulletin 13.
Bulletin 4.

Kentucky

The greater portion of the coals of the state is confined to the eastern part. The cannels seem to occur in thin but continuous beds in the same formations as the bituminous. Often a bed of bituminous will be capped with a few inches cannel or vice versa. The cannel coals of three coal fields in which this type of coal is found, though by no means the predominant coal, will be treated.

Cannels of the Upper Cumberland Coal Field.[37] There is no very considerable area of cannel coal in this region. However, five or six beds contain cannel coal, the Keokee bed in considerable thickness. There is a 39-inch bed of cannel on the Hensley branch, while the nearby Harlan coal bears 23 inches of it.

A thin bed of cannel was found on Sharp's Branch, apparently being of the Keokee bed. The upper coal bed at Bailey Creek contains 11 inches of cannel along with bituminous. This is the continuation of the Harlan coal. The Keokee coal bed at the Jack Bailey Branch bears a bed of cannel coal of most excellent quality, but of most inconstant thickness. At the mouth of the branch its thickness is 30 inches, but 150 yards further up only 11 inches are found. The Keokee bed at Lick Branch bears 28 inches of cannel, also of good quality. The 36-inch bed found at Garner is, however, of poor quality. A bed of 49 inches of impure cannel, grading at the top into cannel slate was shown at Highland Branch. A bed of unknown thickness is located near Sugar Camp Hollow on Big Looney Creek. Cannel coal was found in a slip at Stagger Weed Hollow. No analyses of these cannels are given.

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[36] F. F. Grout, Cannel Coal in Northern Illinois, Illinois Geological Survey, Bulletin 4.

[37] Kentucky Geol. Survey, Bulletin No. 13—The Upper Harlan Coal Field.

Cannel Coals of Bell and Knox Counties.[38] There are a number of excellent veins yielding a good quality of cannel coal in this region. The most extensive are found in the Stinking Creek region. Commencing on the western border of the field and next to the Pine Mountains, we have the Bear Creek region on Big Clear Creek. The first workable coal in the series in this region is the cannel coal bed on Mud Branch. Its thickness here is 45 inches. This is not, however, a prominent cannel elsewhere in the region. Its quality is shown by the following analyses: Moisture, 1.11%; Volatile, 51.60%; Fixed Carbon, 40.40%; Ash, 7.0%. The Chenoa cannel in the Straight Creek region is unimportant. On the Road fork of Stinking Creek the McGuire seam is opened about 400 feet above the creek. This coal has been persistently traced and the seam is one of common bituminous coal of varying thickness replaced by basins or pockets of cannel coal. On the Broughton branch 34 inches of cannel are found, the bed decreasing in thickness and being replaced in part by soft coal. On the Mills branch a maximum of 45 inches is shown. A thin bed of 6 to 8 inches occurs at Jeff Hammond's fork, while 11 inches are shown at Salt Gum fork. The cannel seam is 13 inches at Acorn branch and 8 to 10 inches three and one-half miles from the head of Big Creek. On Moore's Creek 10 to 22 inches of cannel have been found. Above this horizon is another cannel seam. The bed has been opened on the Kentucky river on the north side of Kentucky Ridge opposite the head of Middle Fork, and traced to the ridge between this fork and Big Creek. It shows 13 inches of cannel near the mouth of Middle Fork, and 12 inches at Messer's, a mile further on.

Cannels of the Licking Valley Region.[39] This district contains the largest continuous area of minable cannel coal that has been developed in Kentucky. This is the Caney Creek region, where more than 2,000 acres are underlaid by cannel coal with a workable bed section. The thickness of the cannel coal at various places in this area is 22 1-2, 25, 26, 24, 29, 22 and 21 inches. An average of several analyses gives these results: Moisture, 1.7%; Volatile, 41.0%; Fixed Carbon, 48%; Ash, 8.3%.

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[38] Kentucky Geol. Survey. Bulletin No. 13. The Upper Harlan Coal Field. to Pineville Gap in Bell and Knox Counties.

[39] Kentucky Geol. Survey. Bull. No. 10. Coals of the Licking Valley Region.

An upper cannel coal 170 to 200 feet higher in the series is also an excellent coal. The Cox cannel and the Cecil cannel in the ridge between the Licking and Caney Creek yield 18 to 24 inches of coal. At the head of Main North Fork there is cannel coal whose thickness is 29 to 39 inches, but which shows a relatively large percentage of ash. At Mordecai Creek the bed measures 30 inches and at Rush branch 34 inches. These coals show 16 to 18 per cent ash. At Middle Fork the seam is half cannel, a thickness of 8 to 10 inches. Thin beds are shown in the formation at Beaver Creek. A bed of 40 inches of cannel appears in Elliott County west of the Little Fork valley, and the seam is reported at several points on the right fork of Iron Creek to be 24 to 30 inches thick. In conclusion the Bulletin states that cannel coals are abundant in this region and of excellent quality, some of them better than any others in the state.

In general the cannels of Kentucky seem to be more widespread and the veins appear to be of greater continuity than any of which we know in Missouri and Illinois. Their quality in many cases is also most excellent.

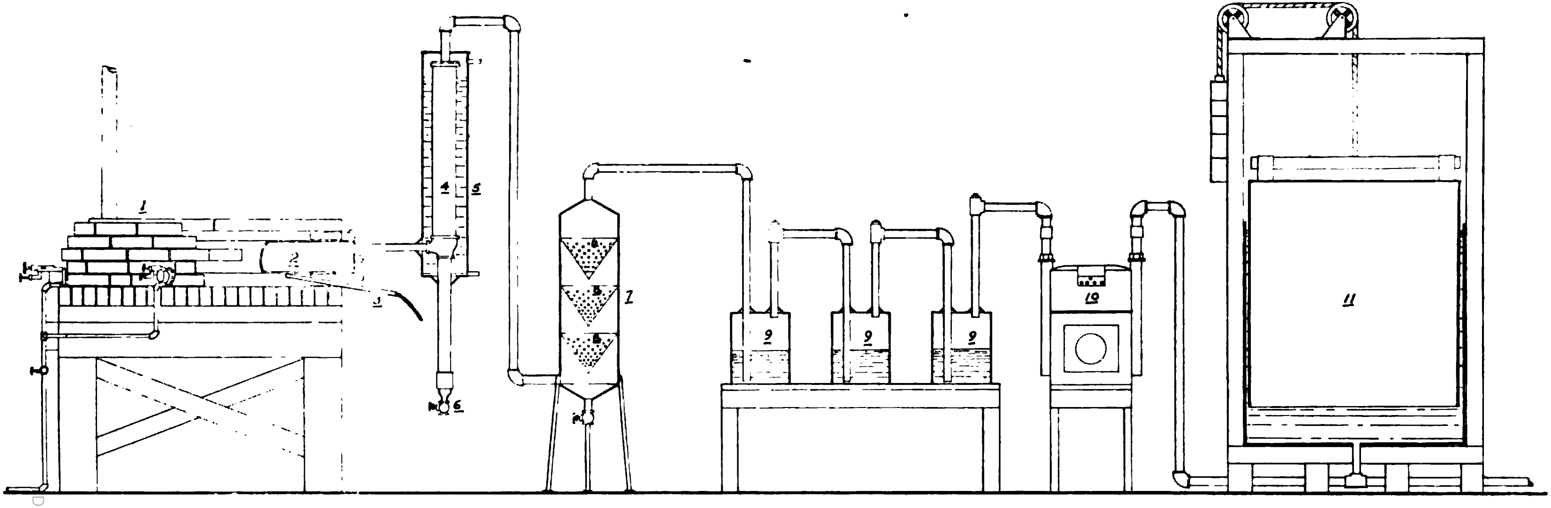

FIG. 1—Apparatus for the Distillation of Coals

THE PRODUCTION OF OILS

Apparatus

The train of apparatus used for the destructive distillation is shown in Fig. 1. It consisted of a *Retort* made of steel pipe six inches in diameter by four feet long and set in a specially designed gasoline fired furnace. This retort had a capacity of about three quarters of a cubic foot which was sufficient to enable the charging of between twenty-five and thirty-five pounds of coal. The pipe was closed at one end with a steel screw-cap and fitted at the other with a flange to which was bolted the steel plate connecting with the condensor. The *Furnace* was heated by three two and one-half inch Case burners placed one on each side and one at the rear.

A Primary Condenser constructed of three-inch pipe surrounded by a galvanized iron water jacket was connected to the retort. A cock located at the bottom provided a means for drawing off the oil.

Before passing into the washers the gas was made to travel through a *Secondary Condenser* which proved very efficient in removing practically all of the remaining tar vapors. This piece of apparatus was built on the "wire drawing" principle and consisted of a cylindrical galvanized iron shell fitted with three inverted cones which were perforated with one-sixteenth inch holes. It was found that even at the maximum gas velocity obtained (thirty-eight cubic feet per hour) only a negligible quantity of oil was carried over into the washers.

The *Gas Washers* shown were galvanized iron cylinders of about one cubic foot capacity which were filled one-fourth full of water. They were all provided with cocks for drawing off the ammonia liquor.

Before going to the storage tank the gas was passed through a master meter.

As it was not found feasible to place the pyrometer rod in the retort, the temperatures during distillation were judged from the readings taken in the furnace. A correction was applied to these readings to obtain the approximate temperature of the coal. This correction was determined experimentally. By manipulation of the burners it was possible to keep the temperatures fairly constant although variations of twenty-five degrees Centigrade were not uncommon.

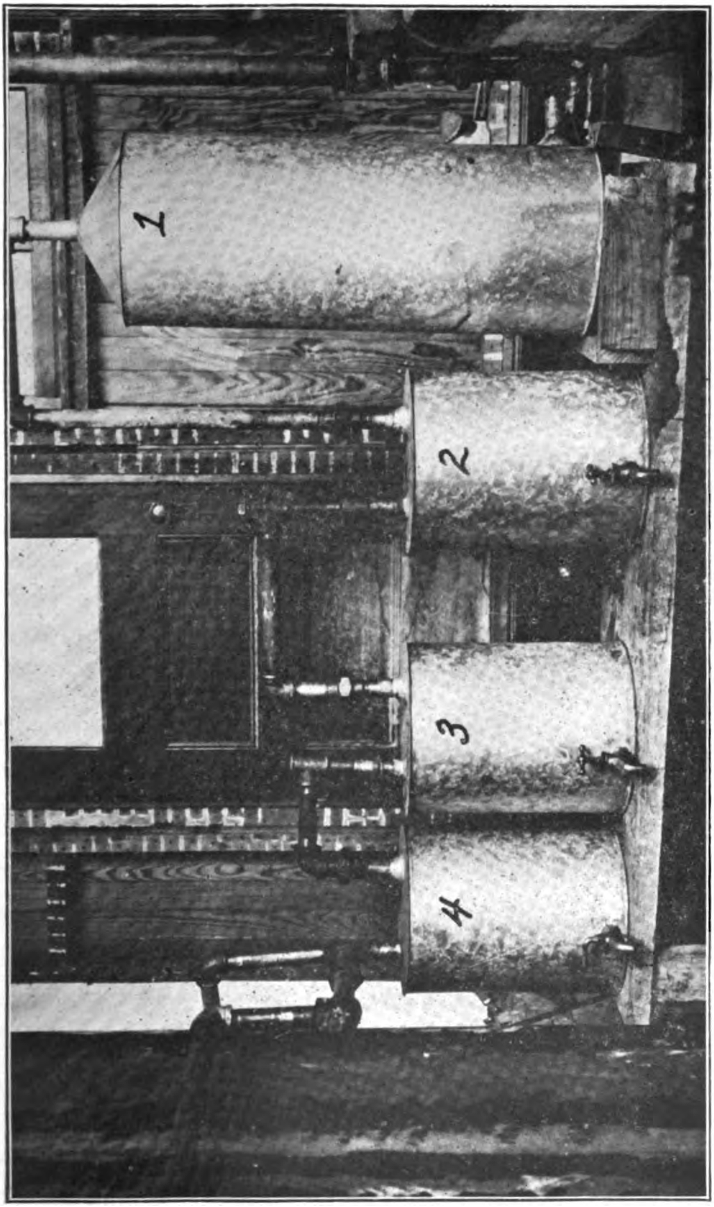

FIG. 2—Secondary Condenser (1), and Gas Washers (2, 3 and 4).

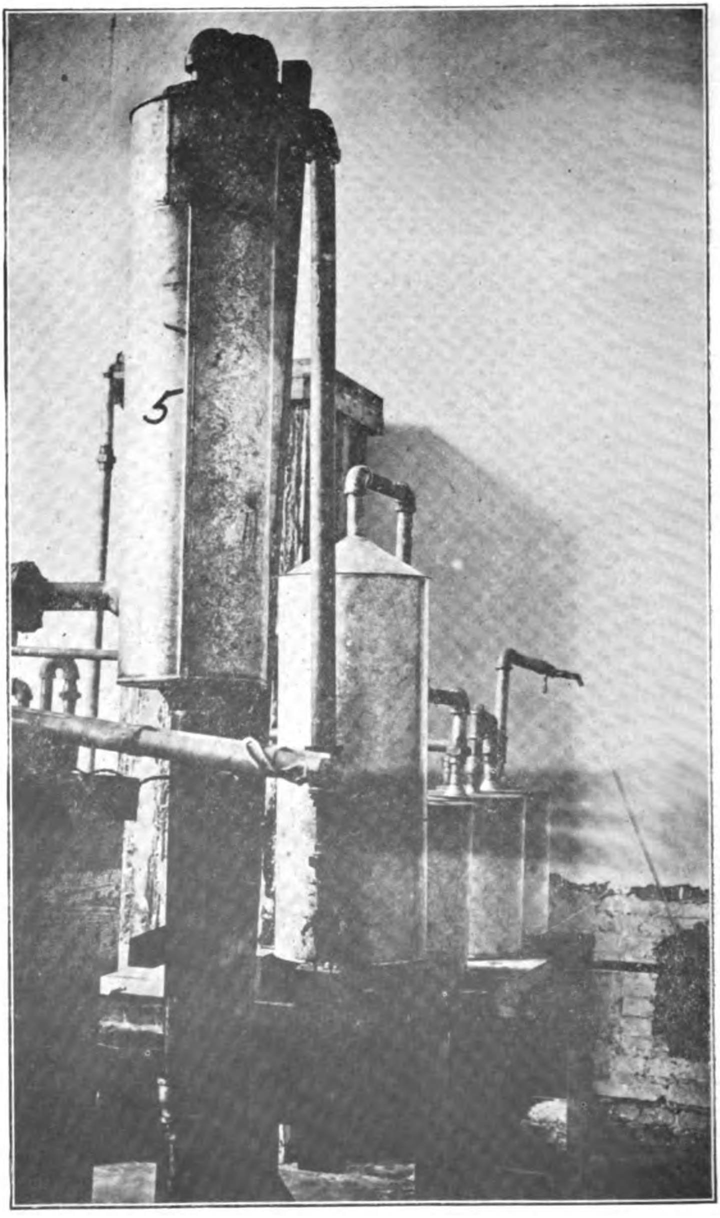

FIG. 3—Apparatus showing Primary Condenser (5)

Mode of Operation

After cleaning out the condensers with fifty per-cent benzol a charge of twenty-two to thirty-five pounds of material was placed in the retort and all connections made gas tight. The material charged was crushed to about one-half inch in the cases of the bituminous and sub-bituminous coal while the cannels were broken into characteristic slivers about three quarters of an inch long, one-half inch wide by one quarter inch thick. Each charge while differing in weight (due to differences in specific gravity of the coals), occupied virtually the same volume, a condition which made possible the duplication of results.

The furnace was then brought as rapidly as possible to the temperature desired and kept at that temperature throughout the distillation or until the production of oil had ceased. The oil produced during each half-hourly period was drained off into liter graduates, the water allowed to separate out and the amounts of both oil and water noted. The separate half-hourly samples were kept for examination in all cases except that of the Wainwright, Mo., cannel coal which was the first material to be run. The gas meter was read every half-hour and the millivoltmeter readings recorded. The data thus collected made possible the study of the rates of production of both the oil and the gas under different conditions of temperature, the retort pressure being constant and equal to that of eight inches of water. Gas samples were collected at the time of maximum production and reserved for analysis.

The above mode of operation is open to three main objections, namely:

1. The temperature control was not as accurate as could have been secured with electric heating;
2. The furnace was not up to the desired heat at the time of charging; and,
3. The draining of the condensers was necessarily subject to lag due to the viscosity of the oil. This error was found to be greatest in the later fractions.

Objections 1 and 2 could easily be overcome by using an electrically heated furnace and a quick method of charging, but the error due to imperfect draining of condensers would be present under all conditions of operation.

In spite of these at present unavoidable difficulties certain data concerning the pyro-decomposition of cannel coal were secured.

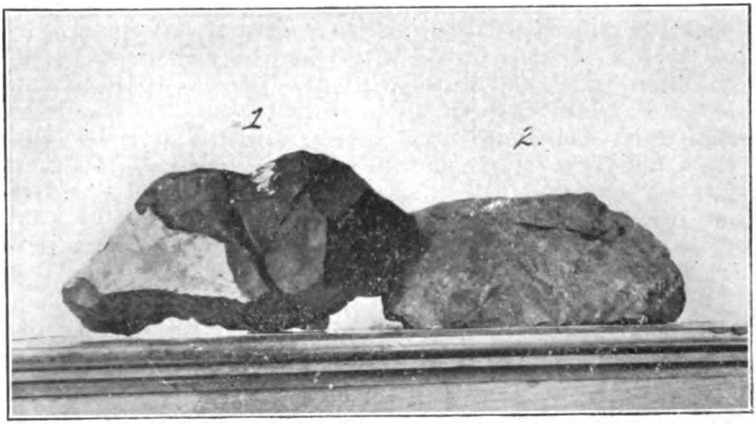

FIG. 4

1—Bunceton, Missouri, Cannel Coal
2—Wainwright, Missouri, Cannel Coal

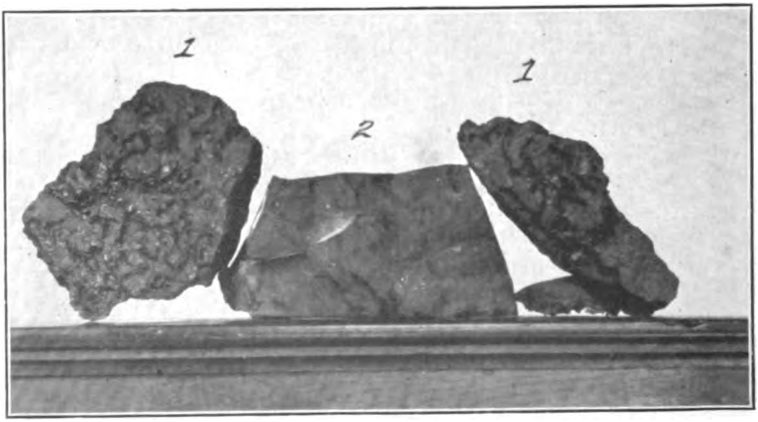

FIG. 5

1—Anaconda, Missouri, Sub-bituminous Coal
2—Herrin, Illinois, Cannel Coal

Materials Used

Cannel Coal—

1. From Wainwright, Callaway County, Missouri.

A rather heavy, black brown, iron stained coal occurring in pockets in south-central Callaway County near the Missouri River. This sample is typical of the poorer grades of North Missouri Cannel Coal.

2. From Bunceton, Cooper County, Missouri.

A very high grade, black, wood-like coal from an unusually large pocket in northern Cooper County, Missouri. It is broken out in large blocks, and splinters on crushing. On being ignited it burns with a very smoky flame and when heated in a test tube fuses or melts before carbonizing. It is by far the best cannel coal encountered in this region.

3 and 4. From Herrin, Williamson County, Illinois.

Two samples of red and brown iron stained coal occurring near the surface in Williamson County, Illinois. They both show prints of ferns, horse tails and other grasses. They differ mainly in ash content.

Bituminous Coal—

5. From Williamson County, Illinois.

Screenings from a high grade bituminous coal from Lumaghi Mine No. 1, Williamson County, Illinois.

Sub-bituminous Coal—

6. From Anaconda, Franklin County, Missouri.

A brownish-black, semi-bituminous coal resembling a lignite in content of water. It is earthy and gives a brown streak. On burning it leaves a small quantity of pure white, pulverulent ash.

The appearance of these coals is shown in Figures 4 and 5.

Analyses.—The proximate analyses and special tests of the materials used are best given in tabulated form and are found in Tables 1, 2 and 3. To furnish a means for comparison the composition of other bituminous substances is given in Table 4.

TABLE 1

Proximate Analyses of Materials Used

	Sp. Gr.	H_2O	Volatile	Fixed Carbon	Ash	Sulphur
Cannel from Wainwright, Mo.	1.382	1.50	32.80	39.20	26.50	3.30
Cannel from Bunceton, Mo.	1.185	0.80	45.20	46.70	7.30	3.00
Cannel from Herrin, Ill., No. 1.	1.463	0.10	38.65	26.10	35.24	0.83
Cannel from Herrin, Ill., No. 2.	1.402	0.60	39.30	35.30	24.80	1.01
Sub-bituminous from Anaconda, Mo.	1.240	19.40	28.10	46.10	6.40	1.21
Bituminous from Williamson Co., Ill.	1.271	4.42	40.04	39.79	15.75	4.10

	Sol. in CS_2%	Sol. in Benzol%
Wainwright	1.64	2.10
Bunceton	4.42	4.10
Herrin No. 7	0.90	0.72

TABLE 2

Ultimate Analyses of Materials Used

(on dry basis)

	Carbon	Hydrogen	phur Sul-	Oxygen and Nitrogen	Ash
Wainwright Cannel	54.80	5.20	3.30	8.60	26.60
Bunceton Cannel	70.50	6.30	3.00	12.10	7.30
Herrin Cannel No. 1	50.90	4.70	0.83	7.77	35.80
Herrin Cannel No. 2	58.90	5.60	1.01	9.79	24.80
Anaconda Sub Bituminous	61.40	7.90	1.21	23.19	6.40
Williamson Co. Bituminous			4.10		15.75

TABLE 3

Composition of Ash of Coals Used

	Al_2O_3	Fe_2O_3	SiO_2	CaO	MgO	Alkalies	P	S
Wainwright Cannel	32.86	13.14	46.20	0.49	1.22	0.96	0.24	0.01
Bunceton Cannel	19.70	18.90	50.40	1.29	1.73	0.58	0.06	none
Herrin Cannel	12.65	25.71	56.44	none	0.58	none	none	none
Anaconda Sub Bituminous	44.72	6.04	46.20	1.29	0.05	0.92	none	0.02

TABLE 4

Composition of Bituminous Substances which have been Subjected to Destructive Distillation

	Water	Carbon	Hydrogen	Nitrogen	Oxygen	Ash
Sphagnum Moss,[40] Germany		49.88	6.54	1.16	42.42	
Peat, Canada,[41] Wet	60.0	22.40	2.80	0.76	12.36	2.40
Dry		56.00	5.20	1.90	30.90	6.00
Black Lignite,[42] Wyoming		54.91	6.39	1.02	32.54	
Lignite, Saxony[43]		65.93	6.03	(Oxygen-Nitrogen) 28.03		11.60
Cannel Coal,[44] England		79.23	6.08	1.18	7.24	4.84
Albertite,[45] New Brunswick		86.307	8.962	2.93	1.971	
Gas Cannel,[46] England		69.00	8.80	1.90	8.90	10.10
Bruxburn Shale,[47] Scotland		20.00	3.00	0.70	0.50	69.80
Bituminous Coal,[48] Pennsylvania		77.14	5.21	1.57	8.65	

Note on the Analyses of Coals. The proximate analyses were carried out according to the directions published by the Committee on Coal Analysis of the American Society for Testing Materials.

In the determination of Carbon and Nitrogen in cannel coals an unlooked for difficulty was encountered. Even when heated very slowly in the combustion furnace these coals gave up comparatively large quantities of methane and volatile unsaturated hydrocarbons which seemed to escape oxidation in the copper oxide zone. An odor of benzol was noticed in the calcium chloride tube used to collect the water, suggesting the formation of aromatic compounds from the aliphatic through the catalytic action of reduced copper[49] at the temperature employed. This difficulty was obviated by passing the gases through another heated copper oxide tube before absorption.

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[40] Jour. Prakt. Chem. 92, 65.
[41] Canadian Dept. of Mines, Mines Branch Bull. 299, p. 133.
[42] U. S. Geol. Survey, Professional Paper 48.
[43] Wagner's Chemical Technology, Crookes and Fisher, p. 20.
[44] Chemical Technology, Groves and Thorp, Vol. 1, Fuels, p. 55.
[45] Baskerville and Hamor, E. & M. J. Vol. 88, No. 4, p. 152.
[46] Blount and Bloxam, Chem. for Engineers and Mfg. Vol. 1, p. 57.
[47] *Ibid*, p. 96.
[48] Benson, Industrial Chemistry, p. 122.
[49] Egloff, Gustav. Private Communication—1917.

In the estimation of Nitrogen the Kjeldahl method was tried without success. The difficulties noted above were again encountered in attempting this determination by Dumas' method. The gas collected would have to be purified by absorption before the true amount of nitrogen could be measured. Work is now in progress on this determination.

Tabulation of Data

Both the tabulated and graphic presentations of the data are included.

Test No. 1—Wainwright Cannel Coal

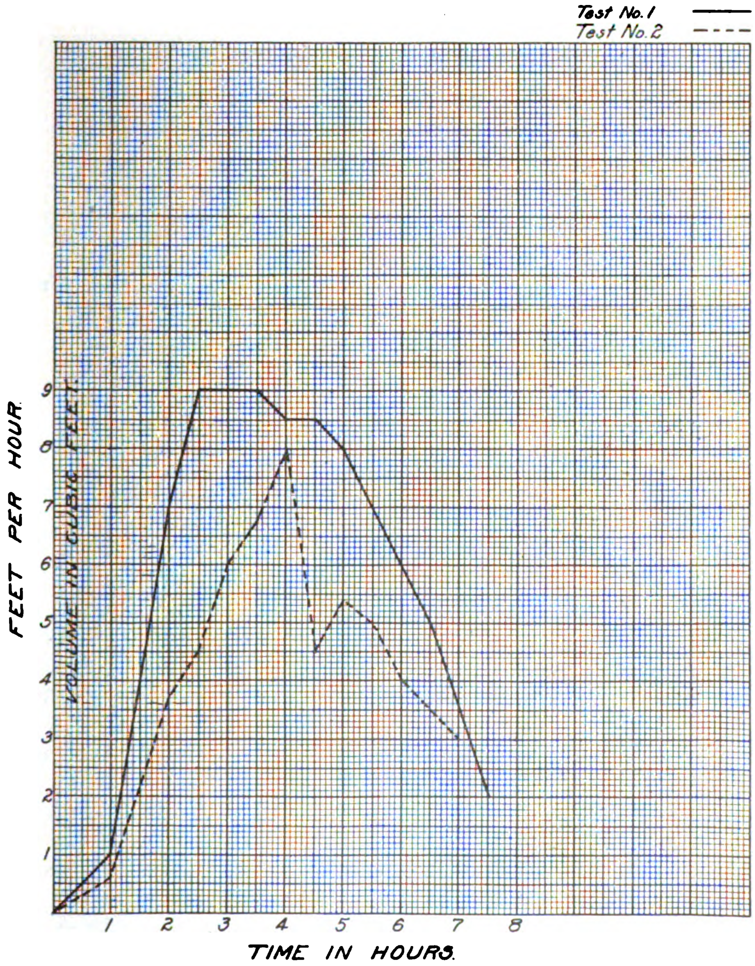
Charge—28.25 pounds
Residue—19.00 pounds 67.12%
Volatile— 9.25 pounds 32.88%

Time in half hours	Gas in Cu. Ft.	Oil in Cu. Cms.	Water in Cu. Cms.	Temp. in °C.
2nd.	1.0	0.0	0.0	Not taken.
3d.	4.0	30.0	50.0	
4th.	7.0	150.0	175.0	
5th.	9.0	220.0	282.0	
6th.	9.0	340.0	130.0	
7th.	9.0	260.0	35.0	
8th.	8.5	220.0	120.0	
9th.	8.5	140.0	30.0	
10th.	8.0	100.0	30.0	
11th.	7.0	80.0	30.0	
12th.	6.0	50.0	10.0	
13th.	5.0	40.0		
14th.	3.5			
15th.	2.0			
Total	87.5	1630.0	892.0	

Yield per Ton—

Gas—7020 cu. ft.
Oil—29.80 gallons.
Water—16.7 gallons.
Residue—1342.4 pounds.

WAINWRIGHT CANNEL COAL.
GAS PRODUCTION TESTS 1&2.



Test No. 2—Wainwright Cannel Coal

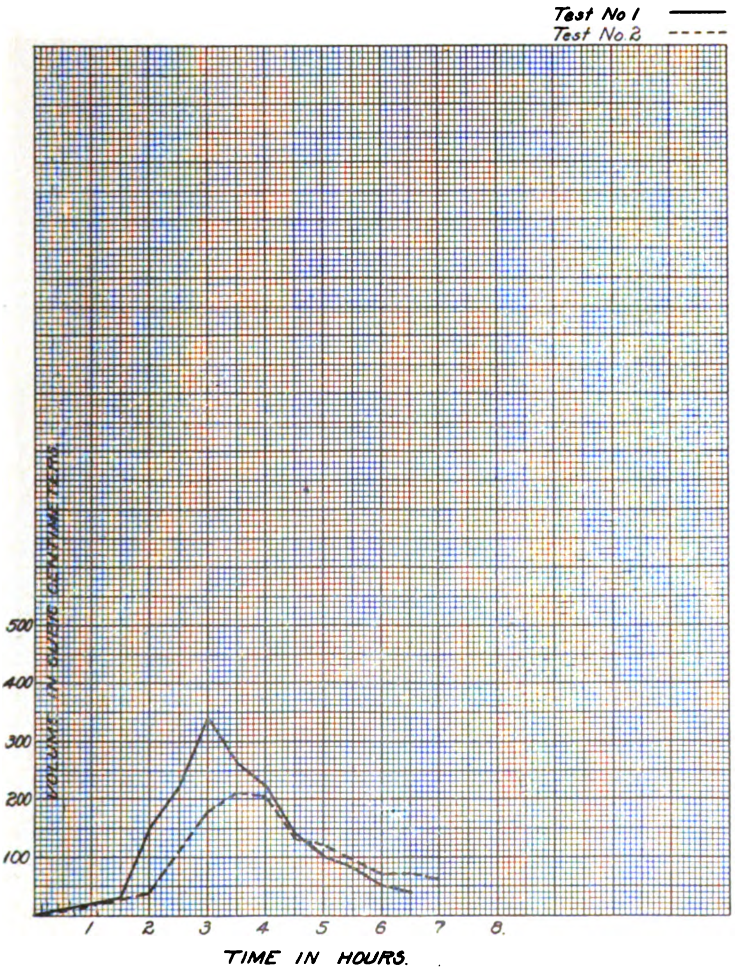
(Temperature lower than in Test No. 1)

Charge—25.25 pounds.
Residue—18.00 pounds 71.30%
Volatile— 7.25 pounds 28.70%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Temp. in °C.
2nd.	0.6	0.0		Not taken.
3rd.	2.0	0.0		
4th.	3.7	40.0	50.0	
5th.	4.5	110.0	175.0	
6th.	6.0	185.0	100.0	
7th.	6.75	210.0	55.0	
8th.	8.0	205.0	80.0	
9th.	4.5	130.0	30.0	
10th.	5.4	125.0	25.0	
11th.	5.0	95.0	25.0	
12th.	4.0	70.0	30.0	
13th.	3.5	70.0	20.0	
14th.	3.0	60.0	25.0	
	56.95	1275.0	615.0	
On Draining		95.0	50.0	
Total	56.95	1370.0	665.0	

Yield per Ton—

Gas—4475 cubic feet.
Oil—28.7 gallons.
Water—13.9 gallons.
Residue—1426.0 pounds.



WAINWRIGHT CANNEL COAL

OIL PRODUCTION TESTS 1 & 2

Test No. 3—Bunceton Cannel Coal

Charge—22.5 pounds

Residue—12.5 pounds 55.5%

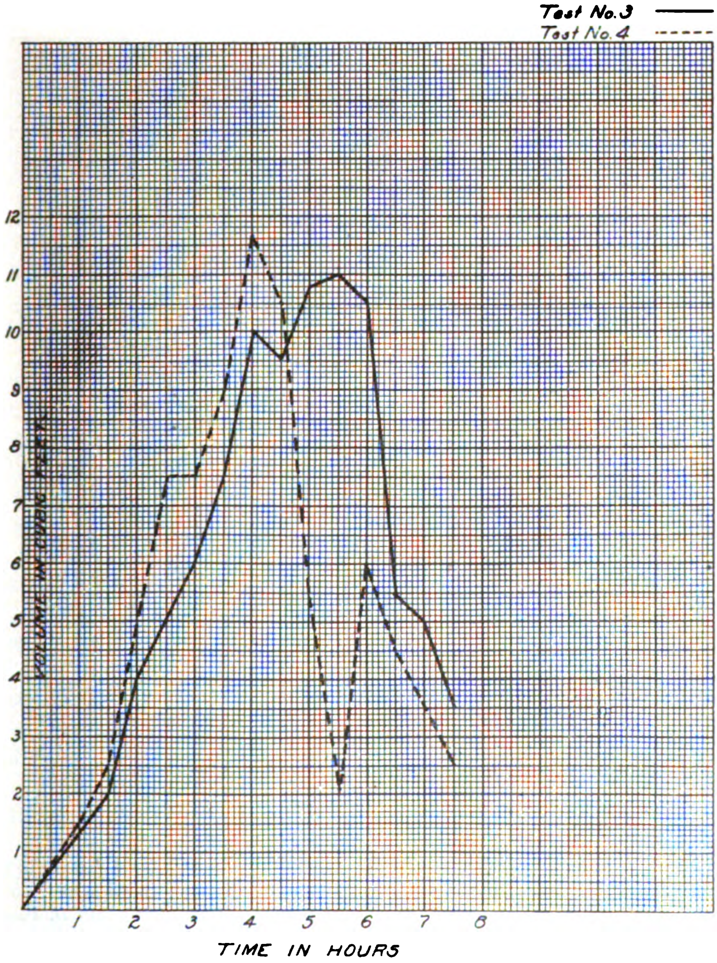
Volatile—10.0 pounds 45.5%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil
2nd.	0.0			
3rd.	2.0	100.0	20.0	0.838
4th.	4.0	160.0	60.0	0.841
5th.	5.0	200.0	45.0	0.866
6th.	6.0	205.0	35.0	0.888
7th.	7.5	325.0	40 0	0.896
8th.	10.0	290.0	20.0	0.904
9th.	9 5	225.0	25.0	0.914
10th.	10.75	205.0	25.0	0.930
11th.	11.0	125.0	10.0	0.953
12th.	10.5	55.0	10.0	0.980
13th.	5 5	35 0	10.0	0.985
14th.	5.0	25.0	5.0	
15th.	3 5			
On draining		175 0		
Total	90.25	2125.0	305.0	

Yield per Ton—

Gas—8100 cubic feet.
Oil—50.0 gallons.
Water—7.2 gallons.
Coke—1110.0 pounds.

Bunceton Cannel Coal.
Gas Production Tests 3 & 4.



Test No. 4—Bunceton Cannel Coal

Retort heated more rapidly than in Test No. 3.

Charge—22.50 pounds.

Residue—12.25 pounds 54.4%

Volatile—10.25 pounds 45.6%

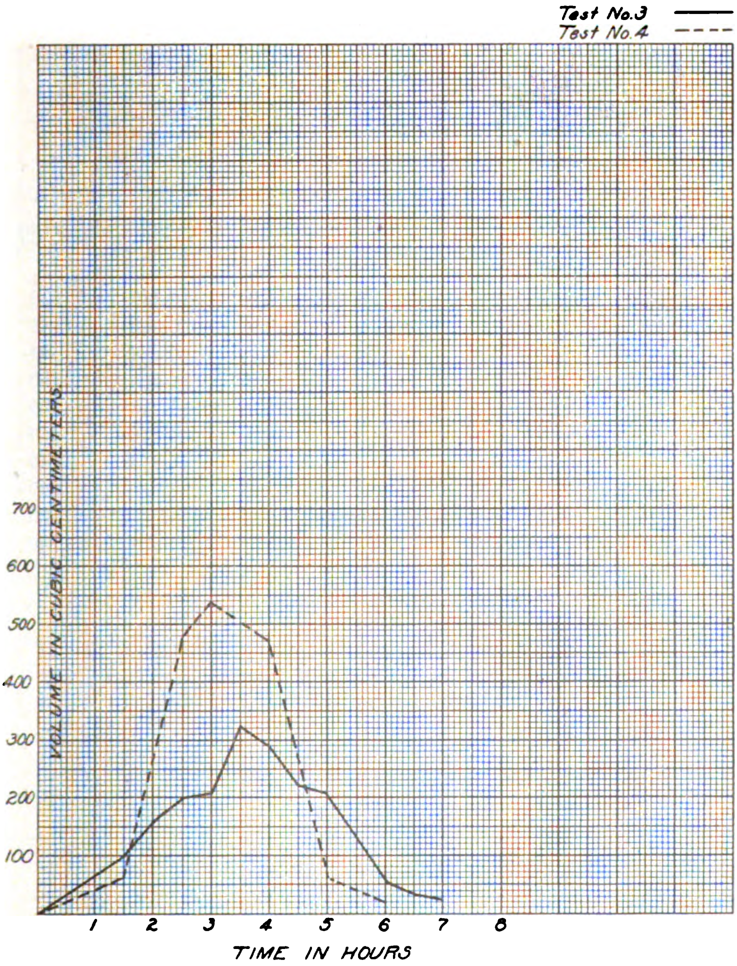
Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	1.5	40.0			450
3rd.	2.5	60.0	5.0	0.850	500
4th.	5.0	250.0	80.0	0.867	540
5th.	7.5	480.0	120.0	0.862	570
6th.	7.5	540.0	60.0	0.875	600
7th.	9.0	505.0	50.0	0.893	600
8th.	11.7	470.0	50.0	0.900	600
9th.	10.5	250.0	25.0	0.910	600
10th.	5.5	65.0	15.0	0.927	650
11th.	2.0	45.0		0.938	650
12th.	6.0	20.0			670
13th.	4.5				700
14th.	3.5				700
15th.	2.5				
On draining		125.0			
Total	79.2	2825.0	405.0		

Yield per Ton—

Gas—7050 cubic feet.
Oil—66.4 gallons.
Water—9.5 gallons.
Coke—1088.0 pounds.

Note: The temperature of the retort is given rather than that of the coal. This temperature is reported to be the more important. (See Whitaker and Crowell—The Effect of Temperature and Duration of Reaction on the Formation of Light Oils in Coals Carbonization at Atmospheric Pressure. Journ. Of Ind. and Eng. Chem. Vol. 9, No. 3, page 263).

Bunceton Cannel Coal.
Oil Production Tests 3 & 4.



Test No. 5—Bunceton Cannel Coal

Charge—21.5 pounds.

Residue—11.5 pounds 53.5%

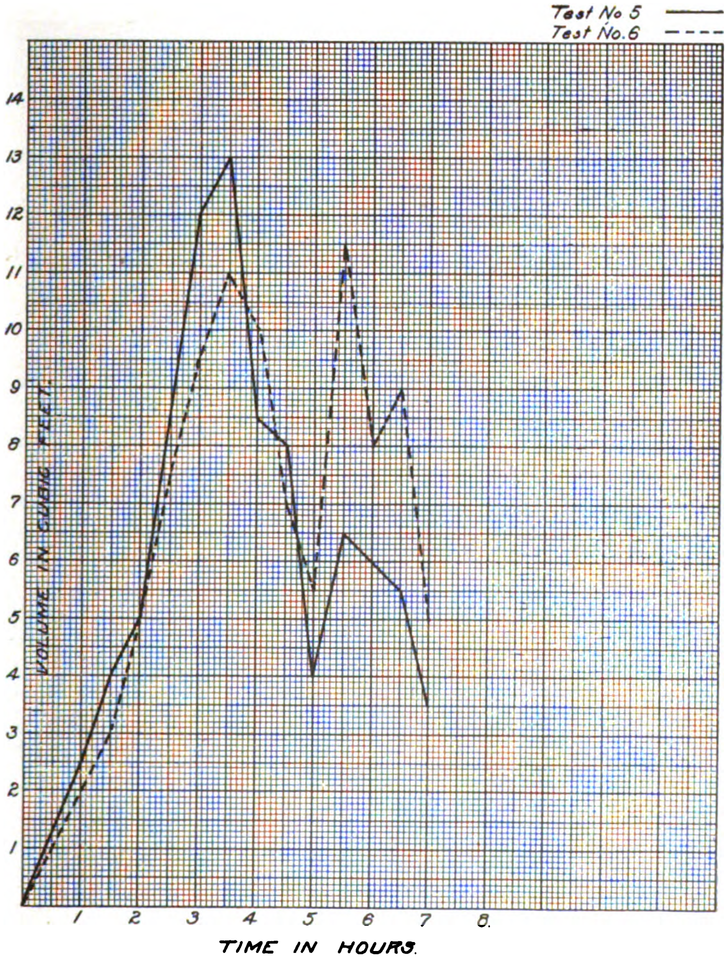
Volatile—10.0 pounds 46.5%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	2.5	130.0	15.0	0.849	420
3rd.	4.0	275.0	90.0	0.858	480
4th.	5.0	615.0	80.0	0.888	500
5th.	9.0	825.0	20.0	0.906	550
6th.	12.0	525.0	25.0	0.918	570
7th.	13.0	240.0	10.0	0.930	600
8th.	8.5	90.0	5.0	0.933	600
9th.	8.0	80.0			600
10th.	4.0	60.0			650
11th.	6.5				700
12th.	6.0				
13th.	5.5				
14th.	3.5				
Total	87.5	2840.0	245.0		

Yield per Ton—

Gas—8138.0 cubic feet.
Oil—69.7 gallons.
Water—6.02 gallons.
Coke—1070.0 pounds.

Bunceton Cannel Coal.
Gas Production Tests 5& 6.



Test No. 6—Bunceton Cannel Coal

Charge—21.5 pounds.

Residue—11.75 pounds 59.0%

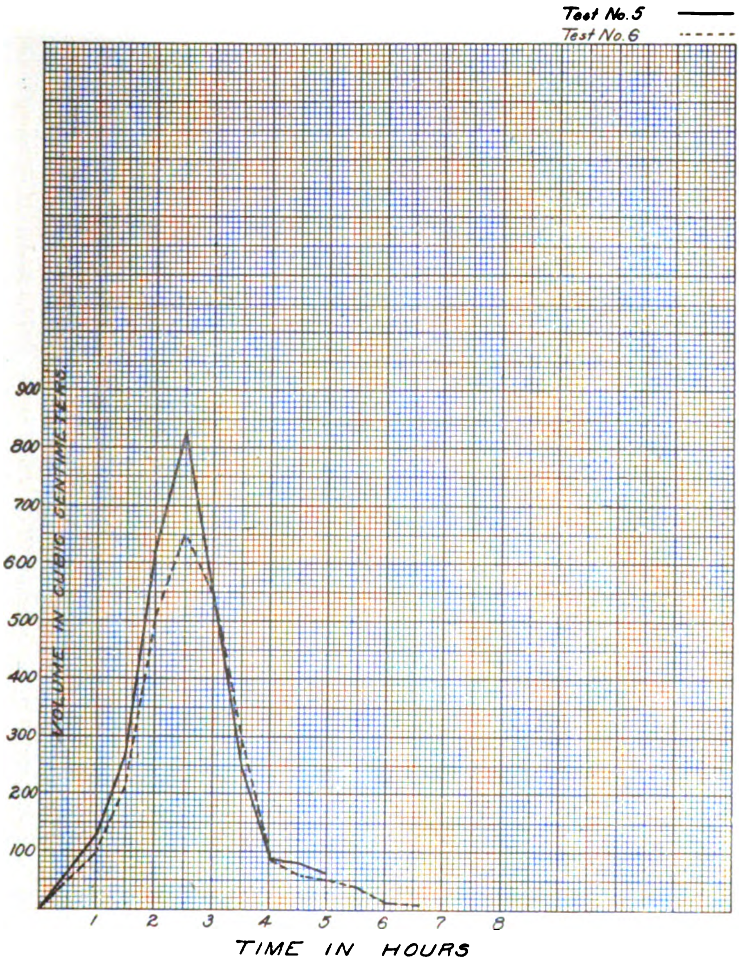
Volatile— 9.75 pounds 41.0%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd	**2.0**	**95.0**	**5.0**	**0.841**	**450**
3rd.	**3.0**	**215.0**	**100.0**	**0.848**	**500**
4th.	**5.0**	**460.0**	**60.0**	**0.870**	**550**
5th.	**7.5**	**650.0**	**30.0**	**0.896**	**572**
6th.	**9.5**	**540.0**	**30.0**	**0.906**	**590**
7th.	**11.0**	**290.0**	**20.0**	**0.916**	**590**
8th.	**10.0**	**90.0**		**0.924**	**620**
9th.	**7.0**	**60.0**			**620**
10th.	**5.5**	**50.0**			**650**
11th.	**11.5**	**40.0**			**675**
12th.	**8.0**	**15.0**			**700**
13th.	**9.0**	**10.0**			**700**
14th.	**5.0**				
On draining		**95.0**			
Total	94.0	2610.0	245.0		

Yield per Ton—

Gas—8375.0 cubic feet.
Oil—64.15 gallons.
Water—6.02 gallons.
Coke—1180.0 pounds.

Bunceton Cannel Coal.
Oil Production Tests 5 & 6



Test No. 7—Herrin Cannel Coal No. 1

Charge—27.25 pounds.

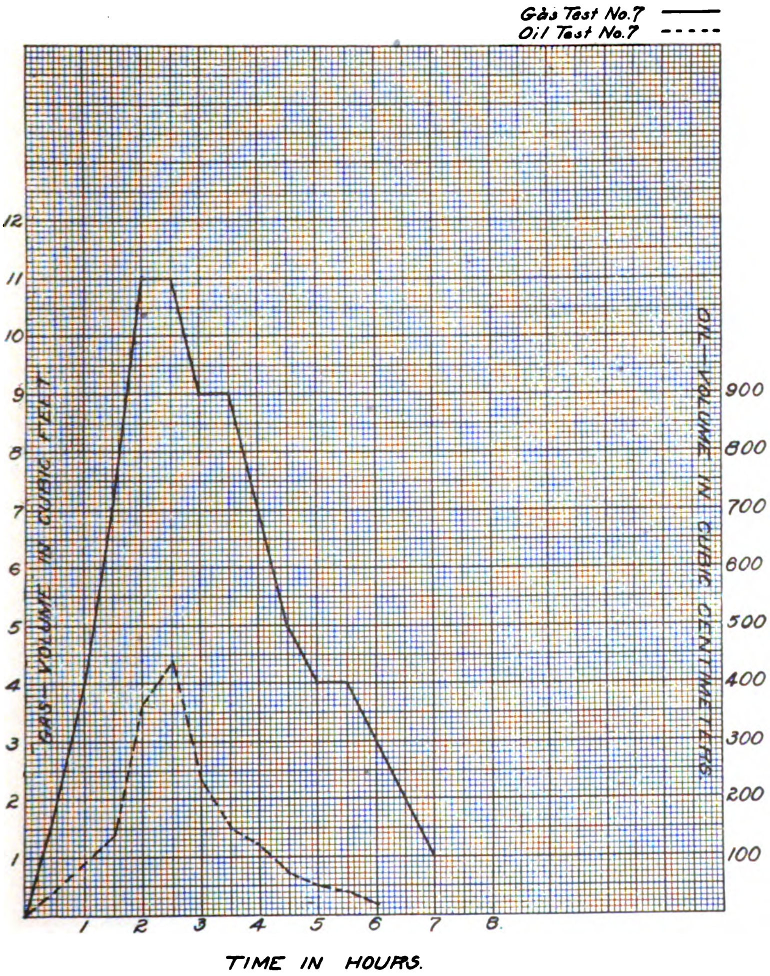
Residue—19.25 pounds 70.6%

Volatile— 8.00 pounds 29.4%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	4.0				450
3rd.	7.0	140.0	100.0	0.890	500
4th.	11.0	360.0	115.0	0.914	550
5th.	11.0	440.0	20.0	0.925	600
6th.	9.0	230.0	20.0	0.946	600
7th.	9.0	150.0	20.0	0.951	600
8th.	7.0	120.0	10.0	0.953	600
9th.	5.0	70.0	5.0		650
10th.	4.0	50.0			650
11th.	4.0	40.0			650
12th.	3.0	20.0			650
13th.	2.0				650
14th.	1.0				650
Total	77.0	1620.0	290.0		

Yield per Ton—

Gas—5655 cubic feet.
Oil—31.4 gallons.
Water—5.63 gallons.
Residue—1412.0 pounds.



Herrin Cannel Coal- No 1
Oil & Gas Production Tests No 7

Test No. 8—Herrin Cannel Coal No. 2

Run at a comparatively low heat

Charge —29.5 pounds

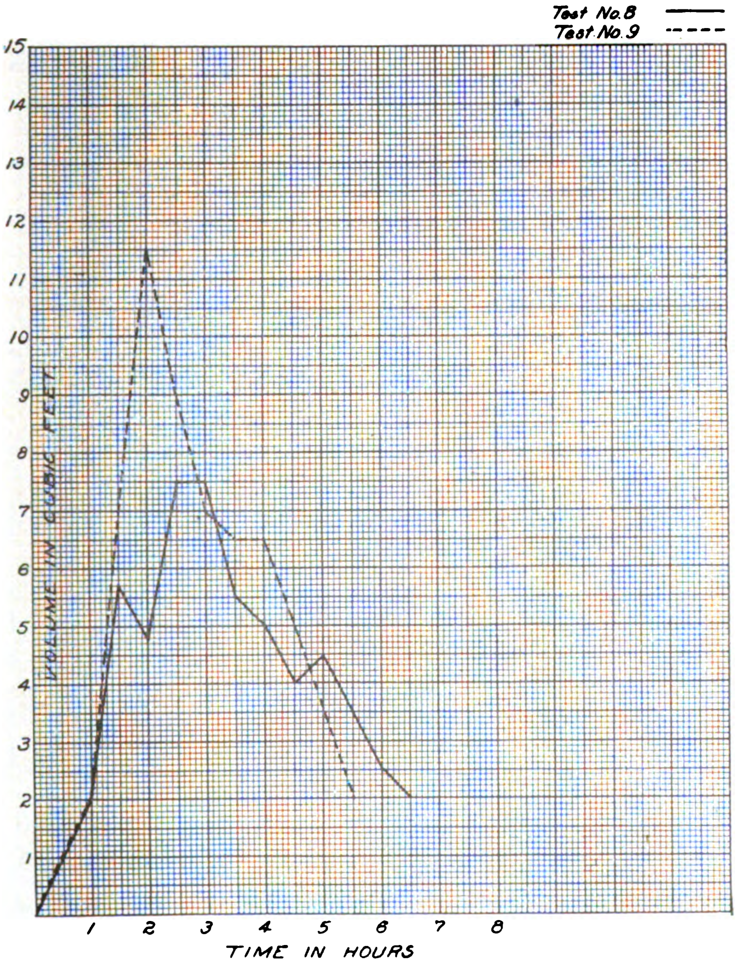
Residue—21.5 pounds 72.9%

Volatile— 8.0 pounds 27.10%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	2.0	160.0	150.0	0.875	420
3rd.	5.75	190.0	110.0	0.892	510
4th.	4.75	300.0	80.0	0.897	550
5th.	7.5	460.0	70.0	0.911	590
6th.	7.5	100.0	20.0	0.900	600
7th.	5.5	75.0	15.0	0.912	600
8th.	5.0	60.0	15.0		600
9th.	4.0	40.0	15.0		600
10th.	4.5	40.0	10.0		600
11th.	3.5	30.0			600
12th.	2.5				600
13th.	2.0				600
On draining		110.0			
Total	54.5	1565.0	485.0		

Yield per Ton—

Gas—3700 cubic feet.
Oil—28.10 gallons.
Water—8.7 gallons.
Residue—1458.0 pounds.



Herrin Cannel Coal–No. 2.
Gas Production Tests 8 & 9

Test No. 9—Herrin Cannel Coal No. 2

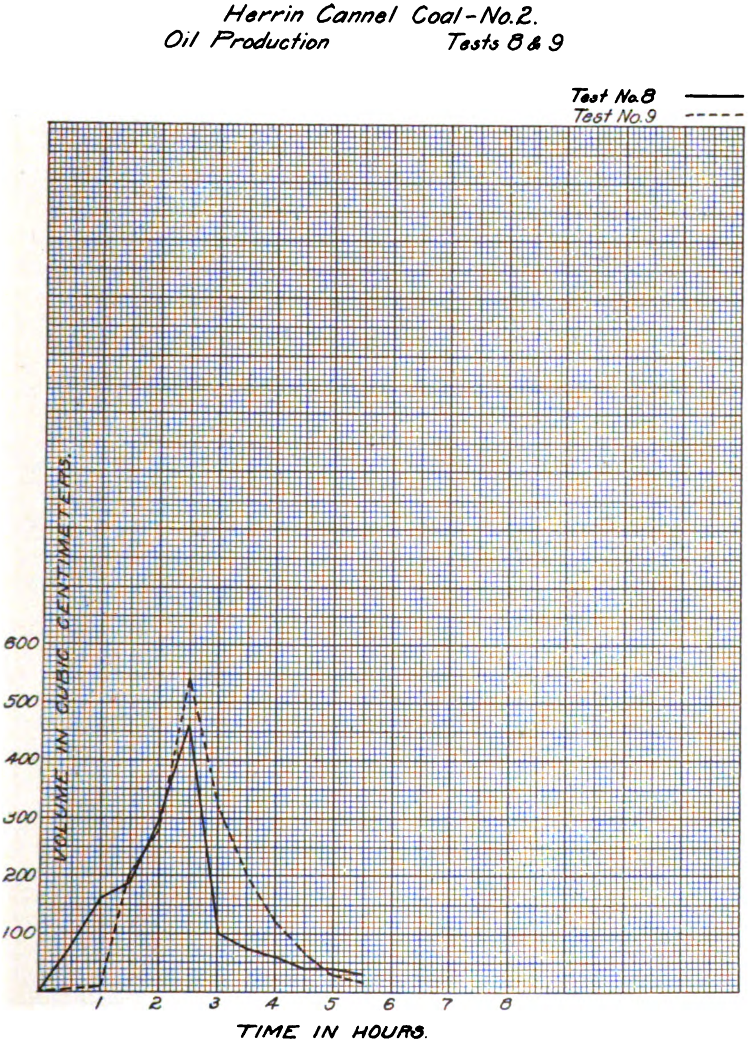
Higher heat than in Test No. 8.

Charge—30.00 pounds
Residue—21.25 pounds 71.00%
Volatile— 8.75 pounds 29.00%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	2.0	7.0	9.0		480
3rd.	6.5	200.0	220.0	0.880	570
4th	11.5	280.0	120.0	0.905	620
5th.	9.0	540.0	80.0	0.910	700
6th.	7.0	325.0	50.0	0.915	700
7th.	6.5	200.0	40.0	0.903	700
8th.	6.5	115.0	25.0	0.900	700
9th.	5.0	65.0	20.0		750
10th.	3.5	35.0	15.0		750
11th.	2.0	15.0	10.0		750
On draining		90.0			
Total	59.5	2035.0	580.0		

Yield per Ton—

Gas—3965 cubic feet.
Oil—34.9 gallons.
Water—10.2 gallons.
Residue—1420.0 pounds.


Herrin Cannel Coal-No.2.
Oil Production
Tests 8 & 9
Test No.8
Test No.9
VOLUME IN CUBIC CENTIMETERS.
600
500
400
300
200
100
1
2
3
4
5
6
7
8
TIME IN HOURS.

Test No. 10—Anaconda Sub-bituminous

Charge —22.25 pounds.

Residue—14.00 pounds 62.30%

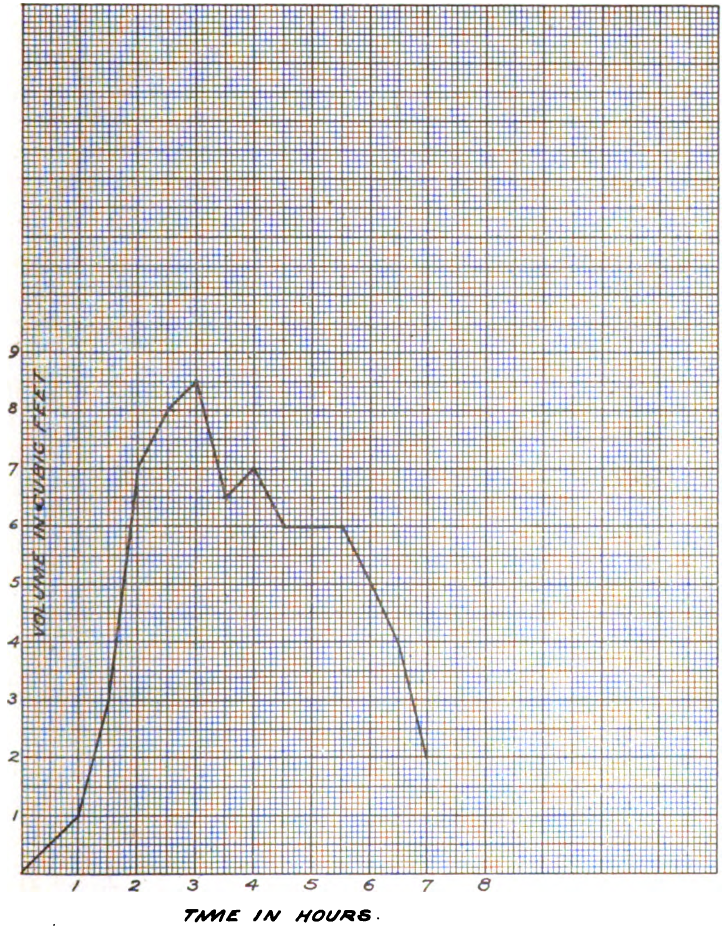
Volatile— 8.25 pounds 37.70%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	1.0				450
3rd.	3.0	10.0	450.0	All heavier than water	500
4th.	7.0	60.0	810.0		550
5th.	8.0	80.0	410.0		570
6th.	8.5	40.0	205.0		600
7th.	6.5	20.0	130.0		600
8th.	7.0	15.0	60.0		600
9th.	6.0		30.0		620
10th.	6.0				650
11th.	6.0				700
12th.	5.0				700
13th.	4.0				700
14th.	2.0				700
Total	70.0	225.0	1695.0		

Yield per Ton—

Gas—6300 cubic feet.
Oil—5.35 gallons.
Water—40.05 gallons.
Residue—1246.0 pounds.

Anaconda Sub-bituminous Coal.
Gas Production Test No. 10



Test No. 11—Williamson County Bituminous

High heat run

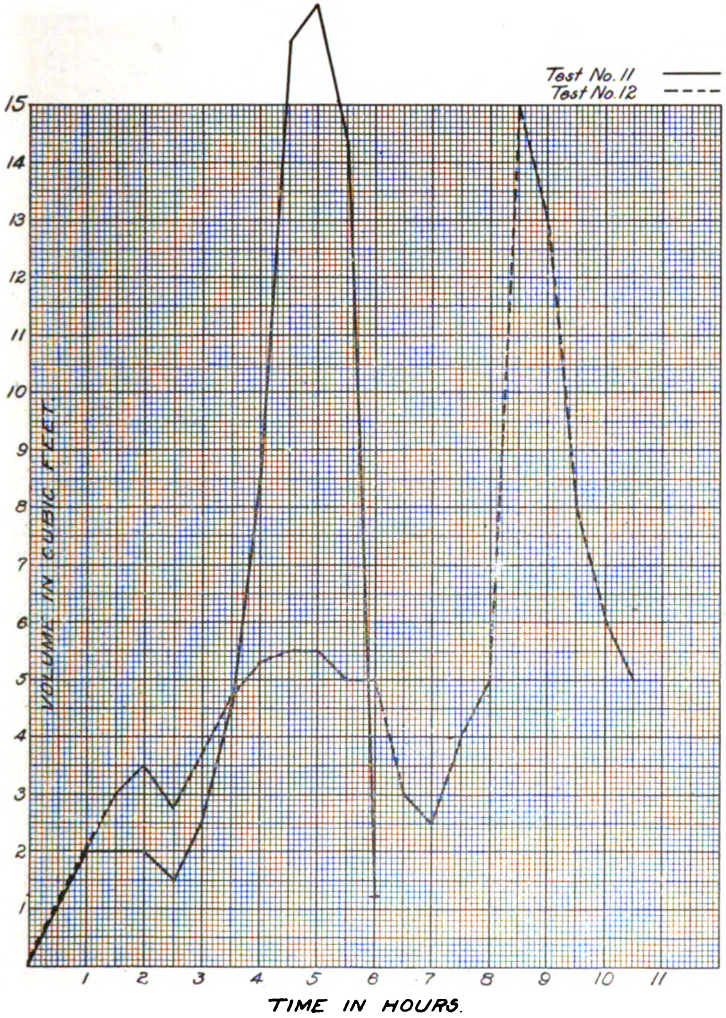
Charge—29.5 pounds
Residue—20.0 pounds 67.8%
Volatile— 9.5 pounds 32.2%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	4.0			Not	450
3rd.	4.0			taken	550
4th.	4.0			"	620
5th.	3.0			"	630
6th.	5.0			"	630
7th.	9.0			"	650
8th.	17.0			"	720
9th.	32.0			"	790
10th.	33.5			"	820
11th.	28.5			"	850
12th.	2.5			"	850
Total	142.5	700.0	2000.0	1.10	

Yield per Ton—

Gas—9547.0 cubic feet.
Oil—12.5 gallons.
Water—35.8 gallons.
Residue—1356.0 pounds.

Williamson County Bituminous Coal.
Gas Production Tests 11 & 12.



Test No. 12—Williamson County Bituminous

Low heat run

Charge—30.25 pounds
Residue—19.25 pounds 63%
Volatile—11.00 pounds 36.4%

Time in half hrs.	Gas in cu. ft.	Oil in cu. cms.	Water in cu. cms.	Sp. Gr. of Oil	Temp. in °C.
2nd.	2.0	0.0	0.0		420
3rd.	3.0	10.0	490.0	Less than 1	450
4th.	3.5	60.0	690.0	Part less, part greater than 1	550
5th	2.75	80.0	380.0	Greater than 1	500
6th.	3.75	120.0	400.0	"	600
7th.	4.7	20.0	480.0	"	600
8th.	5.3	25.0	470.0	"	600
9th.	5.5	25.0	150.0	"	600
10th.	5.5				600
11th.	5.0				600
12th.	5.0				600
13th.	3.0				600
14th.	2.5				600
15th.	4.0				650
16th.	5.0				650
17th.	15.0				720
18th.	13.0				750
19th.	8.0				800
20th.	6.0				800
21st	5.0				800
Total	107.5	330.0	3060.0		

Yield per Ton—

Gas—7080.0 cubic feet.
Oil—5.7 gallons.
Water—53.5 gallons.
Residue—1272.0 pounds.

TABLE 5

Summary of Yields per Ton

Test No.	Gas	Oil	Water	Residue
1.	7020 cu. ft.	29.8 gal.	16.7 gal.	1342 pounds
	14.33%	11.6%	6.95%	67.12%
		0.91 Sp. Gr.		
2.	4475	28.7	13.9	1426
	11.9%	11.0%	5.8%	71.3%
		0.915		
3.	8100	50.0	7.2	1110
	22.5%	19.0%	3.0%	55.5%
		0.912		
4.	7050	66.4	9.5	1088
	16.23%	25.4%	3.97%	54.4%
		0.915		
5.	8138	69.7	6.02	1070
	17.2%	26.8%	2.5%	53.5%
		0.921		
6.	8375	64.15	6.02	1180
	14.0%	24.5%	2.5%	59.0%
		0.914		
7.	5655	31.4	5.63	1412
	14.65%	12.4%	2.35%	70.6%
		0.928		
8.	3700	28.1	8.7	1458
	9.9%	10.6%	3.6%	72.9%
		0.898		
9.	3965	34.9	10.2	1420
	11.5%	13.25%	4.25%	71.0%
		0.909		
10.	6300	5.35	40.05	1246
	18.3%	2.5%	16.9%	62.3%
		1.11		
11.	9547	12.5	35.8	1356
	11.5%	5.7%	15.0%	67.8%
		1.09		
12.	7080	5.7	53.5	1272
	11.4%	2.6%	22.4%	63.6%
		1.08		

Results of Destructive Distillation

The conclusions which the data in Tests 1-12 seem to warrant may be pointed out as follows:

1. The cannel coals yield invariably the larger quantity of both gas and oil when distilled at temperatures not exceeding six hundred degrees centigrade.

2. The liquid hydrocarbons obtained from cannels are true oils possessing a gravity of less than one and containing a comparatively small amount of asphaltic material, while those from the bituminous species being heavier than water and consisting mainly of substances insoluble in petroleum ether, must be classified as tars.

3. The temperatures of decomposition or "cracking" of the original hydrocarbons in the cannel coals are lower than those required to break up the bituminous of the other types, and when "cracked" the latter yield mainly gas and water.

4. With the apparatus and method of heating used, the maximum oil and gas production is attained between the third and fourth hours.

5. The specific gravity of the oil varies with the temperature and rate of heating, and in general the lower temperatures are conducive to the formation of light oils.

PRODUCTS OBTAINED

Gas

Although this product would prove very valuable in an attempt to utilize cannel coals commercially, an exhaustive study of this phase of the subject was not undertaken at this time. Cannel coal gas has been investigated in England where it was used[50] to enrich water gas and ordinary coal gas. In America heavy oils are used in place of cannel coal for enrichment, but the high price of these oils will eventually force the manufacturers to return to the use of the original material. Cannel gas is characterized[51] by the high illuminating and heating value due to its high content of methane, hydrogen and unsaturated hydrocarbons.

A sample of gas collected during the sixth half-hour of Test No. 5, gave the following analysis:

H_2S	1.4 %	by volume.
SO_2	0.90	
CO_2	0.55	
CO	1.75	
O_2	none	
Illuminants (absorbed by $H_2S_2O_7$)	12.2	
CH_4	42.4	
H_2	38.1	
N_2	?	
	97.30	

The above composition would indicate a gas of high candle power (between 26 and 30) and very high calorific power (possibly 900 to 1000 B. T. U.). A yield of eight thousand cubic feet would furnish[52] the total heat for distillation and give a surplus of about three thousand cubic feet.

Ammonia

It is known that in the ordinary methods of destructive distillation at low temperatures, the percentage of nitrogen recovered as ammonia is very low. After distillation the nitrogen exists mainly as nitrogenous organic substances in the oil and coke. This valuable constituent is converted almost entirely into ammonia by the steam distillation process practiced by the Scottish Oil Shale distillers, but by this process the retort residues are rendered worthless.

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[50] Butterfield, W. J. A.—Gas Manufacture, p. 201.

[51] *Ibid*, p. 144.

[52] Private communication—G. B. Evans, Chief Engineer The Laclede Gas Light Co., St. Louis, Mo. 1917.

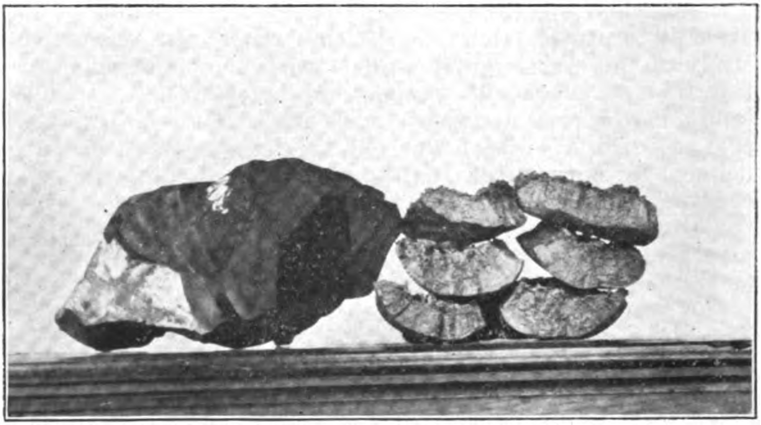

FIG. 6—Coke from Bunceton Cannel Coal

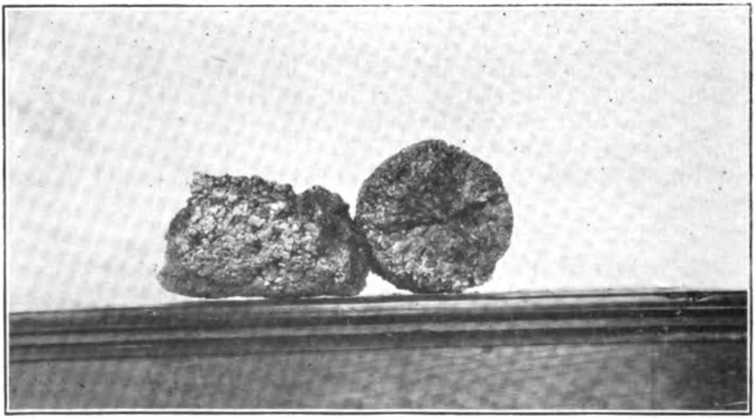

FIG. 7—Coke from Williamson County, Illinois, Bituminous Coal

Difficulties encountered in estimating the quantity of ammonia in the presence of soluble organic nitrogen compounds prevent the inclusion of these data in the present work. It is not expected that the yield of ammonium sulphate would exceed ten to twelve pounds per ton.

Retort Residues

The residual matter from most cannel and low grade bituminous coals is worthless on account of its high ash content. Only one of the samples investigated, that from Cooper County, Mo., made a valuable coke. It has been suggested that certain residues might be used as a substitute for cement shale or as a fertilizer if the ash contain appreciable quantities of phosphorus or potassium.

The composition and character of the residues from the various tests is given in Table 6.

TABLE 6

Analyses and Characteristics of Retort Residues

No. Test	Volatile	Fixed C	Ash	Sulphur	Physical Characteristics
1.	13.9	49.3	36.8	2.19	Partly coked mass. Friable metallic luster.
2.	7.9	56.99	35.11	2.58	Ditto
3.	3.34	82.81	13.85	2.35	Dense, hard coke. Heavier than ordinary coke.
4.	3.8	82.6	13.6	2.14	Ditto
5.	2.4	83.4	14.1	2.15	Ditto
6.	1.1	85.1	13.8	1.74	Ditto
7.	4.52	43.96	51.52	0.40	Uncoked, shaly. No trace of fusion.
10.	6.76	81.64	11.6	1.26	Friable semi-coke. Dull, resembles a charcoal.
11.	2.55	73.82	23.62	3.7	Lustrous, friable coke. Soft and very porous.
12.	7.16	71.34	21.5	3.8	Ditto

The appearance of the original coal from Bunceton, Missouri and the coke made from it is shown in Figure 6. Figure 7 shows a photograph of the coke made from the Williamson County bituminous in Test No. 12.

The Oils and Tars

The liquid hydrocarbon mixtures condensed and collected during the tests classify thesmelves into oils, from the cannel coals, and tars, from the bituminous and sub-bituminous samples. Considerable attention was paid to the oils but no attempt was made to determine the constituents of the tars.

The specific gravity of the several hydrocarbon condensates is given in Table 7.

TABLE 7

Specific Gravity

	Test No.	Sp. Gr.	Degree Baume
1	Wainwright Cannel	0.910	23.8
2	" "	0.915	23.0
3	Bunceton Cannel	0.912	23.5
4	" "	0.915	23.0
5	" "	0.921	22.0
6	" "	0.914	23.1
7	Herrin Cannel No. 1	0.928	20.8
8	" " No. 2	0.898	25.9
9	" " No. 2	0.909	24.0
10	Anaconda Sub Bituminous	1.110	
11	Williamson Co. "	1.090	
12	" " "	1.080	

The cannel oils were brown-yellow when first drawn from the condenser but soon became dark on exposure to the air. The later fractions exhibited the typical petroleum oil fluoresence. The odor of the composite samples was similar to that of a high gasoline crude oil. The specific gravity of these samples varied between 0.898 and 0.928 and that of the separately collected distillates between 0.841 and 0.985. All of the oils precipitated a semi-solid paraffine on standing, this substance being present in greatest amount in "cuts" made during the third, fourth and fifth half-hours.

Although no examination was undertaken to determine the ultimate composition of these complex mixtures, certain tests[53] indicate the presence of the following substances; liquid and solid paraffine, olefines, acetylenes, pyridine and nitrogen bases, cresols and acidic bodies, thiophene and other sulphur compounds and heavy asphaltic material insoluable in petroleum ether.

Examination of Oils. To obtain a sample which would represent the composition of the oil *in toto*, one-third of each half-hourly product was measured out and these portions mixed. This sample was termed a composite. After this had been done the remainder of the half-hourly distillates were combined to give hourly samples, thus insuring sufficient material for the analyses and tests.

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[53] The tests employed are those found in,
The Chemistry of Petroleum—Tinkler and Challenger.
Allen's Commercial Analysis 2nd Edition, Vol. 2, Parts 2 and 3.
Identification of Pure Organic Compounds—Mulliken, Vols. 1 and 2.

All composites and hourly samples were fractionated and the gravities of the fractions determined. The percentage of asphaltic material and solid paraffine was also estimated. A comparison of the unsaturated hydrocarbon content of the fractions was obtained from their relative bromine absorption numbers.

Fractionation. The fractionation was carried out in a standard Engler oil distillation flask with the apparatus set up as shown in Figure 8. A gas regulator was inserted between the pressure regulator and the Tirrill burner in order more accurately to control the heating.

The distillation[54] was carried on at one drop per second from room temperature to 150°C and from 150°C to 300°C, the necessary corrections for protruding mercury thread being made. The residue was then transfered to a 250 c.c. weighed Fry distilling flask and taken to coke. The weight of the flask before and after the coking of the oil gave the amount of asphaltic material.

The fractions collected were:

to 150°C—Naphtha or gasoline fraction.
150-300°C—Kerosene or burning oil fraction.
300-coke —Lubricating oil and paraffine.
coke —Asphaltic material.

Bromine Absorption. In many of the above fractions the weight of bromine absorbed per gram of oil was determined by the usual method.[55] In complex mixtures this does not give sufficient information for calculating the percentage of unsaturated hydrocarbons but merely furnishes a means for comparison with other oils.

Asphaltic Material. Bodies insoluble in petroleum ether were estimated by precipitation from this substance. After decanting the petroleum ether, the insoluble material was dissolved in benzol, and the benzol solution filtered and evaporated in a weighed beaker. The residue on evaporation is termed petroleum ether insoluble asphalt.[56].

Paraffine. The quantitative estimation of the solid paraffines is based upon their insolubility in ethyl-ether-ethyl-alcohol mixture (1:1) at low temperatures. From 0.2 to 0.3 grams of the sample were weighed out into an eight-inch test tube and dissolved in twenty c.c. of ethyl-ether;

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[54] Examination of Hydrocarbon Oils—Holde-Mueller, p. 29.
[55] Commercial Organic Analysis—Allen, Vol. 2. Part 2, p. 25.
[56] Examination of Hydrocarbon Oils—Holde-Mueller, p. 34.

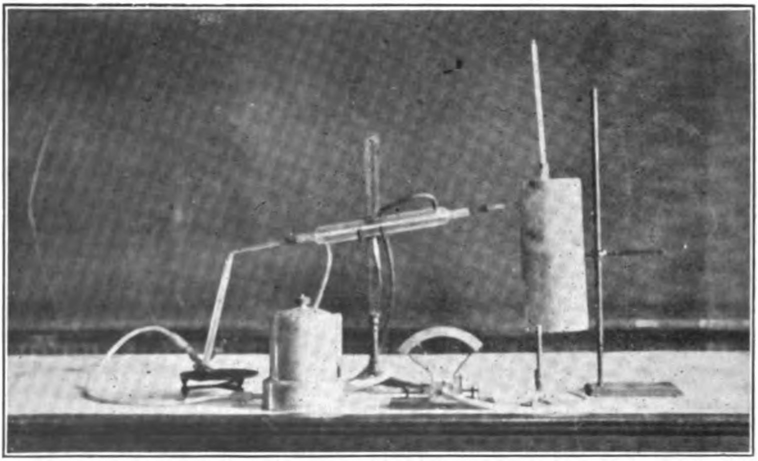

FIG. 8—Apparatus for Fractionation of Oils

1. Pressure control tank.
2. Gas regulator (Graduated arc type).
3. Tirrill burner.
4. Galvanized iron, asbestos lined cylinder to surround standard Engler distilling flask.
5. 60 cc. Liebig condenser.
6. 25 cc. measuring cylinder.

twenty c.c. of ethyl-alcohol were added and the mixture cooled to -20^{0}C. The semi-solid mass was filtered by suction using double filter papers and a four-inch funnel surrounded by freezing mixture.

To separate the paraffine from any asphalt precipitated with it, the former was dissolved by pouring boiling ethyl-alcohol through the filter. The filtrate was collected in a tarred beaker, the alcohol evaporated, and the paraffine weighed. This method gave the amount of hard paraffine (m.p. 45-55^{0}C.) The soft paraffine may be estimated by evaporating the original ether-alcohol filtrate and freezing from a 1 ether-2 alcohol mixture.

COMPOSITION OF OILS AND TARS

Results of Fractionation. Examination of samples of oils taken during distillation gave the results noted in Tables 8-11, below. The composite samples gave the results listed in Table 8. In Tables 9-11 are shown the results obtained from samples taken at intervals during the individual tests.

TABLE 8

Fractionation of Composite Oils

Oils from Test No.	1	2	3	4	5
Specific Gravity	0.910	0.915	0.912	0.915	0.921
First drop distills at °C	76°	78°	78°	74°	75°
To 150°C Gasoline %	11.3	11.7	12.4	11.6	10.2
150-300°C Kerosene %	41.0	42.0	43.0	42.0	41.0
300° C - Coke, Lubric. %	31.0	33.0	34.0	37.0	39.0
Coke %	10.5		7.0	5.5	8.0
Loss	6.2		3.6	3.9	1.8
Sp. Gr. Gasol. Fract.	0.769	0.772	0.76	0.751	0.742
Sp. Gr. Keros. Fract.	0.848	0.854	0.841	0.844	0.839
Sp. Gr. Lubric. Fract.	0.903	0.925	0.933	0.931	0.934

Oils from Test No.	6	7	8	9	11
Specific Gravity	0.941	0.928	0.898	0.909	1.090
First drop distills at °C	78^0	78^0	71^0	75^0	74^0
To 150°C Gasoline %	10.0	9.6	12.6	11.4	12.7
150-300°C Kerosene %	42.0	40.0	51.0	43.0	24.9
300° C - Coke, Lubric. %	35.0	40.0	27.5	32.0	29.9
Coke %	5.0	5.75	6.0	6.0	25.0
Loss	8.0	4.65	4.9	7.6	7.5
Sp. Gr. Gasol. Fract.	0.773	0.781	0.769	0.77	0.901
Sp. Gr. Keros. Fract.	0.868	0.868	0.862	0.865	1.005
Sp. Gr. Lubric. Fract.	0.959	0.951	0.933	0.939	1.049

TABLE 9

Fractionation of Bunceton Cannel Coal

Test No. 3

Time of Coll. of Sample	3 & 4th Half-hrs.	5 & 6th Half-hrs.	7 & 8th Half-hrs.	9 & 10th Half-hrs.
First drop distills at °C	73	76	78	79
To 150°C Gasoline %	20.6	10.0	10.5	11.0
150-300°C Kerosene %	46.0	38.0	40.0	46.0
300° C - Coke, Lubric. %	29.0	35.0	35.0	25.0
Coke	3.5	4.5	6.25	8.0
Loss	0.9	12.5	8.25	10.0
Sp. Gr. of Gasoline	0.764	0.761	0.789	0.8
Sp. Gr. of Kerosene	0.844	0.850	0.863	0.878
Sp. Gr. of Lubric.	0.922	0.925	0.941	0.991

Test No. 4

First drop distills at °C	75	75	76	80
To 150°C Gasoline %	19.4	9.0	7.4	7.0
150-300°C Kerosene %	51.0	39.5	40.0	40.0
300° C - Coke, Lubric. %	23.0	40.5	37.0	35.0
Coke	3.25	5.5	7.0	7.7
Loss	3.35	5.5	8.6	10.3
Sp. Gr. of Gasoline	0.778	0.774	0.77	0.792
Sp. Gr. of Kerosene	0.855	0.868	0.872	0.887
Sp. Gr. of Lubric.	0.959	0.938	0.949	0.985

Test No. 5

Time of Coll. of Sample	2 & 3rd Half-hrs.	4 & 5th Half-hrs.	6 & 7th Half-hrs.	8 & 9th Half-hrs.
First drop distills at °C	71.0	76.0	74.0	80.0
To 150°C Gasoline %	21.7	7.9	8.0	7.0
150-300°C Kerosene %	47.5	38.5	36.0	41.0
300° C - Coke, Lubric. %	24.0	41.0	40.5	25.0
Coke	5.0	6.0	8.25	9.5
Loss	1.8	6.6	7.25	17.5
Sp. Gr. of Gasoline	0.773	0.77	0.779	0.782
Sp. Gr. of Kerosene	0.858	0.865	0.872	0.885
Sp. Gr. of Lubric.	0.947	0.95	0.958	0.989

TABLE 10

Herrin Cannel Coal No. 1

Test No. 7

Time of Coll. of Sample	3 & 4th Half-hrs.	5 & 6th Half-hrs.	7 & 8th Half-hrs.
First drop distills at °C	72	79	78
To 150°C Gasoline %	16.6	8.2	9.2
150-300°C Kerosene %	41.0	37.5	43.0
300° C - Coke, Lubric. %	32.0	30.0	30.0
Coke	4.75	2.5	4.7
Loss	5.65	21.8	13.1
Sp. Gr. of Gasoline	0.786	0.77	0.781
Sp. Gr. of Kerosene	0.869	0.862	0.88
Sp. Gr. of Lubric.	0.945	0.952	0.97

TABLE 11

Herrin Cannel Coal No. 2

Test No. 8

Time of Coll. of Sample	2 & 3rd Half-hrs.	4 & 5th Half-hrs.	6 & 7th Half-hrs.
First drop distills at °C	72	76	77
To 150°C Gasoline %	17.5	10.0	10.1
150-300°C Kerosene %	50.0	49.5	63.0
300° C - Coke, Lubric. %	22.0	30.5	18.5
Coke	3.5	2.75	4.75
Loss	7.0	7.25	3.65
Sp. Gr. of Gasoline	0.77	0.763	0.782
Sp. Gr. of Kerosene	0.858	0.859	0.860
Sp. Gr. of Lubric.	0.952	0.945	0.940

Test No. 9

First drop distills at °C	68	78	76
To 150°C Gasoline %	14.0	8.6	9.4
150-300°C Kerosene %	48.0	38.0	45.0
300° C - Coke, Lubric. %	30.0	40.0	30.0
Coke	4.0	6.0	5.0
Loss	4.0	7.4	10.6
Sp. Gr. of Gasoline	0.768	0.77	0.77
Sp. Gr. of Kerosene	0.855	0.871	0.87
Sp. Gr. of Lubric.	0.941	0.932	0.946

Bromine Absorption. The bromine number was calculated and reported as grams of bromine absorbed by one hundred grams of oil. The results of a few of the determinations carried out on certain fractions from cannel oils are given.

TABLE 12

Bromine Number

GASOLINE		KEROSENE	
From Oils in Test No.	Bromine No.	From Oils in Test No.	Bromine No.
1	100.7	1	86.8
2	99.3	2	85.3
3	58.7	3	49.6
4	59.4	4	48.0
5	61.5	5	54.0
11	96.7	11	121.0

LUBRICATING OIL

From Oils in Test No.	Bromine No.
1	58.8
2	36.0
3	37.35
4	
5	58.5

TABLE 13[57]

Comparison with Bromine Numbers of Oils from Other Sources

Gasolines—	
From Shale Oil	67.2
From American Petroleum	18.3[58]
From Cannel Oil	58.7
Kerosenes—	
From Shale Oil	51.3
From American Ptroleum	34.0
From Russian Petroleum	2.0
From Cannel Oil	48.0-49.0
Lubricating Oils—	
From Shale Oils	25.6
From American Petroleum	11.7
From Russian Petroleum	4.9
From Cannel Oil	36.0

The above results show that in content of unsaturated hydrocarbons the cannel oils resemble those obtained in the Oil Shale Industry. The lower bromine absorption of the former points to a higher content of saturated compounds.

---

[57] Taken mainly from Commercial Organic Analysis—Allen, 3d edition, Vol. 2, Part 2, p. 95.

[58] The value 18.3 for the bromine number of gasoline from American petroleum does not apply to that made by cracking process. Gasoline formed from heavier oils would show a much higher absorption.

Paraffine Content. Examination as to Paraffine Content gave the results shown in Tables 14-16.

TABLE 14

Paraffine Content—Composite Samples

Test No.		Hard Paraffine M. P. Above 45°C	Soft Paraffine M. P. Below 45°C
1.	Wainwright Cannel	4.3%	
2.	" "	6.6	5.0
3.	Bunceton "	5.9	4.35
4.	" "	5.0	4.27
5.	" "	4.7	4.04
7.	Herrin Cannel No. 1	2.3	4.47
8.	" " No. 2	6.7	
9.	" " No. 2	12.27	

TABLE 15

Paraffine Content—Samples taken during Distillation

Test No. 3

BUNCETON CANNEL

Time	Hard Paraffine
3rd half hour	2.96
4th " "	6.5
5th " "	7.3
6th " "	8.7
7th " "	6.15
8th " "	4.55
9th " "	4.05
10th " "	4.12
11th " "	3.26

BUNCETON CANNEL

Test No.	Time	Temp. °C.	Hard Paraffine Per Cent	Soft Paraffine Per Cent
4.	3 & 4th Half-hrs.	520	1.54	2.42
4.	5 & 6th " "	585	5.97	2.0
4.	7 & 8th " "	600	7.03	3.22
4.	9 & 10th " "	600	6.36	5.96
5.	3 & 4th Half-hrs.	500	4.33	2.40
5.	5 & 6th " "	570	9.90	5.10
5.	7 & 8th " "	600	11.90	5.93
5.	9 & 10th " "	600	8.90	6.15

The lubricating oil fraction of all samples contained so much paraffine that it became semi-solid at ordinary temperatures. A determination of the paraffine content of several of these distillates is given below.

TABLE 16

Paraffine in Lubricating Oil Fractions

	Hard Paraffine Per Cent
Bunceton Cannel Test No. 3	28.8
" " Test No. 5	25.2
Williamson Co. Bit. Test No. 11	8.5

Asphalts or Bitumens. Results of examinations as to per cent of asphalt are shown in Tables 17 and 18.

TABLE 17

Asphalt Per Cent—Composite Oils

Test No.	Asphalt per cent
1	6.77
2	8.33
3	5.34
4	4.69
5	5.93
6	5.04
7	4.95
8	2.72
9	2.33

TABLE 18

Asphalt Per Cent—Half-Hourly Samples

Test No. 3,	Bunceton Cannel	Test No. 4,	Bunceton Cannel
Time in Half-hrs.	Asphalt per cent	Time in Half-hrs.	Asphalt per cent
3rd	0.78	3rd	1.90
4th	1.57	4th	2.74
5th	2.64	5th	2.65
6th	3.02	6th	3.35
7th	3.83	7th	4.03
8th	5.55	8th	5.12
9th	8.37	9th	7.99
10th	12.04	10th	8.71
11th	21.19		
12th	25.1		

Test No. 5, Time in Half-hrs.	Bunceton Cannel Asphalt per cent
3rd	
4th	1.95
5th	2.87
6th	4.82
7th	5.26
8th	8.93
9th	11.92
10th	10.0

Discussion of Results

The lower temperatures seem to be productive of the larger quantities of light oil but the cracking process which goes on at the higher heats causes the formation of some gasoline. Evidence of this thermal decomposition of the heavier bodies is found in the greater distillation losses in the later fractions (see Table 9). The coke or asphaltic material consists partly of the residues (carbon) of this cracking.

The intermediate fractions contain smaller quantities of kerosene and larger quantities of lubricating oil and solid paraffine. This is readily explained by the fact that at the time of formation of these portions the decomposition temperature of the heavier bodies had not yet been reached (see Table 9 and 10).

The difference in quality of the oils from the four cannel coals used is so slight that one may be justified in saying that, distilled under similar conditions, these materials will yield distillates of approximately the same composition (see Table 8). The specific gravities of the "cuts" made on the cannel oils do not differ widely and average about 0.770 for the gasoline, 0.850 for the kerosene and 0.940 for the lubricating oil.

Although the hydrocarbons obtained from the bituminous coal at low temperatures contained some paraffine the content of asphalt was high enough to give the mixture a specific gravity greater than one. This mixture did not resemble the cannel oils in appearance and exhibited characteristic tar properties. It was found impossible to separate the water from these tars in any other way than by distillation, the settled tar then yielding about twenty per cent of water. On fractionation the different distillates showed the presence of the aromatic compounds benzol. naphthalene and diphenyl.

In Table 15 it is shown that the production of paraffine reaches a maximum between the fifth and eighth half-hours, while the last oils drawn contain the largest amount of soft paraffine. In other words, a temperature of about 600°C is conducive to the formation of the higher members of the methane series; below that temperature they are not produced and above 600° they are decomposed.

Another evidence of cracking is found in Table 18. The amount of naphtha insoluble bodies (asphalts or bitumens) increases with the time and temperature of distillation. Table 17 shows the amounts of these substances in the composite oils.

SUMMARY

1. Samples of cannel and bituminous coals were destructively distilled in a horizontal gas-fired retort under approximately the same conditions and found to yield entirely different results.

2. The bituminous varieties were mainly productive of small quantities of tars while the cannel coals yielded comparatively large amounts of oils.

3. The oils consisted largely of liquid and solid hydrocarbons of the methane and olefine series together with cresols and asphaltic bodies. The constituents of the tars were paraffines and olefines, aromatics and a large proportion of bitumens.

4. The cannel oils averaged about 11% gasoline (similar to that produced commercially by the cracking process), 40% kerosene and 40% lubricating oil containing 25% of solid paraffine.

5. Maximum gasoline production was obtained by distilling between 450° and 550°C. Hard paraffine and kerosene were formed in largest quantity between 550° and 650°C while above 650°C soft paraffines, heavy oils, kerosene and bitumens were the main products.

6. A yield of between 3500 and 8100 cubic feet per ton of very rich gas was obtained from the several cannel coals, the time of maximum production being between the fifth and sixth half-hours.

7. Only one sample, that from Bunceton, Mo., gave a salable coke.

8. The process of destructive distillation for the production of oils from coal seems to be one of low-temperature cracking. The very heavy hydrocarbons which are the results of the decomposition of cellulose break up into simpler compounds (mainly aliphatic) on application of heat. At higher temperatures those bodies formed by the primary cracking might be again cracked with the formation of aromatic hydrocarbons nad asphaltic substances. The comparatively high olefine content of the oils obtained should greatly facilitate such a rearrangement.

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UNIVERSITY OF MISSOURI

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THE HYDROMETALLURGY AND THE ELECTROLYTIC PRECIPITATION OF ZINC

ROLLA, MISSOURI

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SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

THE HYDROMETALLURGY AND THE ELECTROLYTIC PRECIPITATION OF ZINC

BY

FLOYD DIXIE JAMES, B. S.
Research Assistant,
Junior Member, A. I. M. E.

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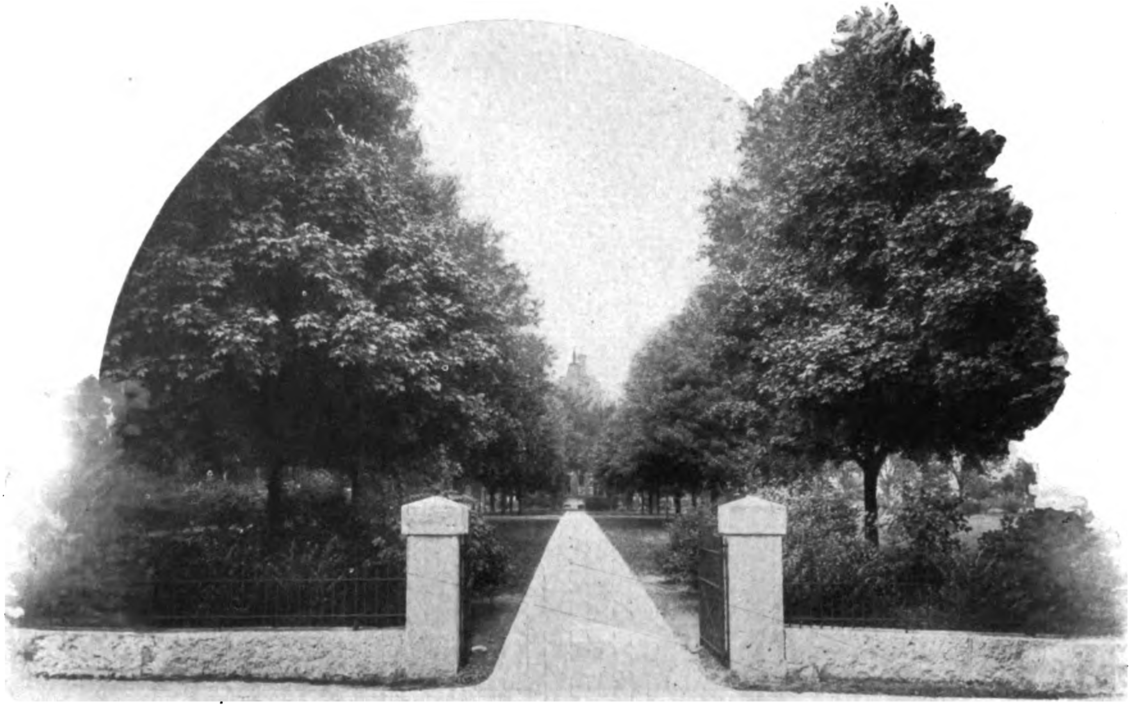

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THE HYDROMETALLURGY AND ELECTROLYTIC PRECIPITATION OF ZINC.

The idea of extracting zinc from ores by electrolytic methods is not new, for many schemes have been tried in the past. Electricity has been used as a source of heat in electric smelting, and for its chemical action in aqueous electrolytic processes. Until recently the methods devised did not give encouraging commercial results. The electrical methods have not given favorable results in this country, although Norway with its cheap electric power produces a considerable tonnage of spelter in this manner. The work being done in this country is on aqueous electrolytic processes, and has been successful to an extent which has warranted the erection of several commercial plants.

The literature on this subject is very meagre. So far the metallurgists conducting experiments on the hydrometallurgy of zinc have made only general statements.

The purpose of this bulletin is to collect some of the more important information available on this subject, and to give the results of a series of experiments which were made on a number of ores, chosen to represent the typical ores of several districts. The experiments were carried on under the most favorable conditions, the objects being to find the maximum extraction possible, and to determine the types of ore amenable. No attempt was made to approximate commercial conditions. The problem is divided into five parts, which are discussed under the following headings:

I. Ores used.
II. Roasting of sulfide ores.
III. Leaching of the ore.
IV. Purification of the solution.
V. Electro-deposition of the zinc from the leach liquors.

Before discussing the first topic, the general method of carrying on the experimental work will be given, as this will make the steps following more easily understood.

The method of procedure was as follows: The ore was sampled. Complete analyses were made, both chemical and mechan ical. The sulfide ores required roasting to convert the zinc into a soluble form. Test lots were made for roasting; and if the ore was coarse, it was crushed to the mesh which was thought necessary for good roasting. The test lots, generally of 2,000 grams each, were roasted in the muffle of a coal-fired assay furnace, and a temperature record of each roast kept. A platinum platinum-rhodium thermocouple and a millivoltmeter were used, and the temperatures were read at intervals of about five minutes and the results recorded. The temperature records for the last series of roasts were recorded by Leeds-Northrup recording potentiometers.

The roasted ore was leached with a dilute sulfuric acid solution. The strength of the acid, the amount of acid used, and the time of leaching were varied and the results noted. The leach liquor was filtered from the residue and the residue washed free from acid solution. The extractions were ordinarily calculated from the weights and assays of the raw ore, roasted ore and residue from the leaching. If the results did not check in a satisfactory manner, the leach liquor was weighed and analized and the zinc in the solution and residue required to check the zinc in the original roasted ore within 2%.

The purification of the solution was the next step. Various methods of oxidizing the iron were tried. The solution was neutralized both with crushed limestone and with high-grade roasted ore. The copper, cadmium, etc., were removed with zinc dust and the solution filtered. The clear solution was used in the electrolytic cells.

The solution was electrolyzed, lead anodes and aluminum cathodes being used. The current density and the acidity of the electrolyte were varied, addition agents were tried, and the results noted.

I. Ore used

The ores used for this work were chosen to represent the typical ores of several districts.

Ore A. is a western high grade flotation concentrate. It has the following composition:

Zn	51.18
Fe	4.43
S	30.05
Pb	2.40
Cu	1.33
Mn	0.38
CaO	0.12
Insoluble	4.02
	93.91

Screen Analysis

Through	On	Percent
......	35	00.00
35	48	18.91
48	65	4.58
65	100	9.40
100	150	14.65
150		52.46
		100.00

Ore B. is a high grade jig product of the rosin jack variety. It has the following composition:

Zn	52.07
Fe	6.19
S	29.82
Pb	0.51
Cu	0.00
Mn	0.00
CaO	0.13
Insoluble	5.06
	93.78

Screen Analysis		
Through	On	Percent
......	14	00.0
14	20	30.5
20	35	52.7
35	48	7.8
48	65	3.4
65	100	2.1
100	150	1.1
150	200	0.5
200		0.9
		100.00

Ore C. is the same ore as B., except that it is a table product. It has the following composition:

Zn	54.35
Fe	4.62
S	29.68
Pb	1.82
Cu	0.00
Mn	0.00
CaO	0.11
Insoluble	4.68
	95.26

Screen Analysis		
Through	On	Percent
......	10	0.00
10	14	0.15
14	20	0.38
20	28	1.02
28	35	3.88
35	48	7.97
48	65	11.00
65	100	21.93
100	150	28.22
150	200	12.71
200		13.24
		100.00

Ore D. is a jig middling, and is used to represent the low grade complex zinc ores. It has the following composition:

Zn	21.58
Fe	22:37
S	33.75
Pb	0.75
Cu	0.78
Mn	0.21
CaO	0.14
Insoluble	12.62
	92.20

Screen Analysis		
Through	On	Percent
......	3	00.00
3	4	11.85
4	6	16.85
6	8	11.60
8	10	10.30
10	14	7.90
14	20	5.90
20	35	12.30
35	48	5.40
48	65	4.80
65	100	4.50
100	150	2.60
150	200	2.70
200		3.30
		100.00

Ore E is a mixed blende and silicate ore. It has the following composition:

Zn	50.47
Fe	0.89
S	9.61
Pb	0.00
Cu	0.00
Mn	0.00
CaO	0.09
Insoluble	16.36
	77.42

Screen Analysis		
Through	On	Percent
......	8	0.0
8	10	19.9
10	14	22.0
14	20	13.1
20	28	7.3
28	35	5.5
35	48	5.2
48	65	5.3
65	100	7.4
100	150	5.3
150	200	2.5
200		6.5
		100.00

Ore F. is a high grade silicate ore. No complete analysis made.

II. Roasting of sulfide ore

The sulfide ores must be roasted to convert the zinc into zinc oxide or sulfate so that it can be dissolved in a dilute sulfuric acid solution. There are two general schemes possible for roasting this material: (1) the oxidizing roast, and (2) the sulfatizing roast. The object of the oxidizing roast is the complete elimination of the sulfur, the zinc remaining as zinc oxide. The object of the sulfatizing roast is to oxidize all the zinc sulfide present to zinc sulfate, and to leave no unoxidized zinc sulfide. Zinc oxide is readily soluble in sulfuric acid solutions and zinc sulfate is readily soluble in water.

In the early work on the hydrometallurgy of zinc, the sulfatizing roast was tried because the zinc sulfate formed was readily soluble in water. Great difficulty was experienced in converting all of the zinc to the sulfatizing condition. The extractions were low and the sulfate roast was finally discarded.

The present commercial plants appear to have started out to make a complete desulfurization or dead roast; that is, to convert all of the zinc to zinc oxide. This has always been the aim of the retort smelters, so information and data were readily obtained along this line.

The processes now in use seem to have been based on the use of the oxidizing roast because the metallurgists could figure on the results to expect from it. As the plants are giving the results expected, their metallurgists are experimenting with the sulfatizing roast. This will lower the cost of treatment, as it will materially lessen the acid consumption per pound of zinc.

Regardless of which roasted product you desire, the complete elimination of sulfur as sulfide is essential.

Zinc sulfide is practically insoluble in dilute sulfuric acid solutions, and each pound of sulfur, as sulfide in combination with zinc, renders two pounds of zinc insoluble.

Care must be used in its elimination, for at elevated temperatures zinc ferrite is said to form. Zinc ferrite causes no difficulties in retort smelting, as it requires only a little extra heat to decompose it in the retort. But in hydrometallurgical processes it is fatal, because being insoluble in dilute acids it causes large zinc losses. Some metallurgists assert that zinc ferrite forms at low temperature, and they regulate the roaster temperature accordingly, while others assert that high temperature is required for it to form.

The time that the ore is roasted is important as well as the temperature. The longer and harder an ore is roasted the denser will be the resulting product due to the molecular stresses which are set up. The physical condition of the ore plays an important part in the ease of solubility of the roasted ore. This may increase the time required to leach the zinc from the ore, or it may cause a lower extraction, for some of the zinc may have been rendered insoluble. One writer[1] gives zinc ferrite as 20 per cent soluble in cold 10 per cent sulfuric acid. Mr. W. McA. Johnson[2] says that by heating zinc ferrite at 1300° C. for twelve hours he obtained a hard, dense zinc ferrite which was practically inert chemically. The ferrite used by the former writer could not have been so strongly ignited.

It is known that ignition renders zinc oxide less easily soluble in caustic solution, and time and temperature play an important part in the degree of solubility. This should also hold for other solvents. Therefore, when roasting for hydrometallurgical purposes, it seems the temperature should be held as low as is consistent with good work and the ore roasted as rapidly as possible. The conclusion from this is that the possibility of zinc ferrite formation is not the only reason for the careful regulation of the roasting conditions.

The present tendency toward the sulfate roast makes iron in the ore beneficial, as it is difficult to obtain a good sulfate roast on a blende that is low in iron. While the iron aids in sulfate roasting, it also makes the production of zinc ferrite possible, unless the temperature can be controlled to prevent it. The metallurgist who can control roaster conditions to produce a maximum of zinc sulfate and at the same time avoid an excessive formation of zinc ferrite and unoxidized zinc sulfide will be able to treat any of the low-grade complex ores successfully.

The writer finished some roasts at a high temperature to bake the iron and render it insoluble in dilute sulfuric acid. This

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1. **Wells:** The Ferrites, Compounds of an Iron Acid. "Engineering and Mining Journal," Aug. 29, 1908.

2. The Role that Zinc Ferrites play in Hydrometallurgy. "Metallurgical and Chemical Engineering," Jan., 1913.

was easily done; but as some of the zinc as well as the iron was apparently rendered insoluble, and as it was found that a considerable quantity of ferric iron was not harmful in electrolysis, this method was abandoned. A certain amount of iron is necessary in the solution during purification to remove arsenic and antimony. It is more efficient to dissolve it from the ore than to throw in scrap.

The practice of using carbon to aid desulfurization in the roasting furnace does not appear to have a place in roasting for leaching work. The carbon at the low temperature of a roaster will decompose zinc sulfate according to the equation[3]:

$$ZnSO_4 + C \rightarrow ZnO + SO_2 + CO$$

This would defeat our purpose, as a maximum amount of zinc sulfate is desired. The effect of carbon on zinc ferrite at the temperature of the roaster is not known by the writer. Coal added to an ore which had been roasted to a low sulphur content gave a roasted product which gave a better extraction on leaching than the ore not treated with coal. When the loss of zinc in roasting was investigated, the ore to which coal had been added showed a loss about three times the regular roast. The gain in the leaching was only a small percentage. The following table shows the results obtained:

Table No. 1.

Roast No.	Leach No.	Mesh	Max. Temp. Centegrade.	Time in Hours	Percent Sulphur		Percent Zinc			Percent of Zinc lost in Roasting.	Percent of Zinc Extracted in Leaching.	Percent of Zinc Extracted from Raw Ore.
					Raw	Roast	Raw	Total	Water Soluble			
3	27	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	95.8	91.01
3	28	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	95.2	90.44
3	29	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	95.3	90.54
3	30	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	95.2	90.44
3	31	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	95.3	90.54
3	32	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	95.4	90.63
3	33	67%-100	824°	2.5	33.5	2.15	50.8	59.3	—	5.00	80.36	76.34
4	34	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	95.4	81.09
4	35	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	87.8	74.63
4	36	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	98.01	83.31
4	37	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	97.95	83.26
4	38	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	98.8	83.98
4	39	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	96.2	81.77
4	40	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	96.5	82.03
4	41	65%-100	824°	3.5	33.5	0.19	50.8	60.6	—	15.0	95.4	81.09

Roast No. 3, was on Ore A. Roasted in usual way.

Roast No. 4, was coal added to the above roast and rabbled to remove last traces of sulphur.

The low results on leaches No. 33 and No. 35, were probably due to insufficient quantity of acid.

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[3] Ingalls: Metallurgy of Zinc and Cadmium, 2d ed., 1906. Page 31.

The latest patent[4] on this work says: "A pre-reduction of the ore is obtained." If zinc ferrite is rendered soluble by this process, it may have a place in roasting for hydrometallurgical work, provided the gain in extraction offsets the increased roasting loss due to the zinc which is reduced and volatilized. This loss may be avoided by means of bag houses or the Cottrell process. The roof of the roaster building, where this process is used, was white the last time the writer saw it. The value of this practice is doubted by many metallurgists, even when used for the retort process.

Apparatus used for roasting.—The roasts were made in a three muffle, coal-fired assay furnace. The floor surface of each muffle was 12 by 19 inches, and it was 7.5 inches to the top of the arch. The rabbling of the ore was done with a small, flat, iron paddle similar to those used in hand reverberatory roasters. A small iron hoe was also used.

The temperature measurements were made with a platinum platinum-rhodium thermocouple and a Wilson-Maulen millivoltmeter. The temperatures were taken every five minutes and the results recorded. The records for the long roasts were obtained by using two Leeds-Northrup recording potentiometers. The instruments recorded continuously and a good temperature curve was obtained.

The thermocouple junctions were enclosed in fused quartz tubes to protect them from the ore and the rabbles.

The method of procedure in roasting was as follows: Charges of 2000 grams were placed in the muffle and the temperature gradually raised until the ore began to roast. The ore was placed so as to cover approximately one square foot of hearth area. The thermocouple was placed in the muffle against the side wall, and the junction was kept about half way back in the muffle.

The junction was generally exposed to the air, but several times was covered with the ore to get the ore temperature. The couple lay against the ore, but was covered with it when the readings were taken.

The ore was thoroughly stirred every five minutes for most of the roasts, although on several it was rabbled almost continuously. The ore was discharged hot from the furnace on most of the roasts, but several roasts were allowed to cool in the furnace.

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[4] "Engineering and Mining Journal," July 8, 1916.

The results of the roasts of the several ores are shown in the following tables:

Table No. 2.

ORE A. DATA ON ROASTS.

Roast No.	Mesh.	Max. Temp. Centegrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron		Percent of Zinc lost in Roasting.
				Raw	Roast	Raw	Roast	Raw	Roast	
1	52%-100	788°	2.16	33.5	6.34	50.8	58.2	4.4	5.0	3.9
2	53%-100	804°	2.25	33.5	0.28	50.8	60.4	4.4	5.1	7.0
3	67%-100	824°	2.5	33.5	2.15	50.8	59.3	4.4	4.6	5.0
4	65%-100	824°	3.5	33.5	0.19	50.8	60.6	4.4	5.2	15.0
5	67%-100	828°	1.75	32.63	3.19	50.7	59.1	4.8	4.9	1.5

The data in Table 2 shows that the extraction of zinc is inversely proportional to the amount of sulfur left in the ore.

Table No. 3.

ORE A. TIME ROASTS AND SULFATE ROASTS.

Roast No.	Mesh.	Max. Temp. Centegrade.	Time in Hours.	Percent Sulphur		Percent Zinc			Percent Iron	
				Raw	Roast	Raw	Roast Total	Roast Water Soluble	Raw	Roast
1a	39%-100	608°	4	32.63	16.88	50.7	50.8	9.02	4.8	4.4
1b	39%-100	608°	6	32.63	13.06	50.7	48.6	12.12	4.8	4.0
1c	39%-100	608°	8	32.63	12.10	50.7	48.6	13.28	4.8	4.1
1d	39%-100	608°	10	32.63	12.48	50.7	48.1	13.91	4.8	3.7
2a	40%-100 Lumps +8	710°	2	32.63	20.3	50.7	56.9	0.23	4.8	5.1
2b	40%-100 Lumps +8	877°	4	32.63	5.8	50.7	58.2	3.43	4.8	5.3
2c	40%-100 Lumps +8	916°	6	32.63	3.02	50.7	58.6	3.28	4.8	5.4
2d	40%-100 Lumps +8	916°	8	32.63	3.20	50.7	59.2	3.90	4.8	5.3
3a	42%-100Lumps-8'mesh	982°	2	32.63	10.5	50.7	59.0	—	4.8	4.9
3b	42%-100Lumps-8'mesh	982°	4	32.63	0.77	50.7	62.5	—	4.8	5.1
3c	42%-100Lumps-8'mesh	982°	6	32.63	0.48	50.7	62.6	—	4.8	4.9
3d	42%-100Lumps-8'mesh	982°	8	32.63	0.48	50.7	61.8	—	4.8	5.2
4a	60%-100 Lumps on 8	616°	4	32.86	25.16	51.8	53.5	3.35	4.1	4.2
4b	60%-100 Lumps on 8	616°	5	32.86	21.46	51.8	54.2	4.13	4.1	4.6
4c	60%-100 Lumps on 8	616°	6.5	32.86	17.46	51.8	55.3	6.27	4.1	—
5a	——	580°	5	32.86	17.05	51.8	52.5	3.90	4.1	4.3
5b	——	580°	6	32.86	21.29	51.8	52.5	2.80	4.1	4.5
5c	——	580°	7	32.86	16.96	51.8	52.2	3.65	4.1	4.3

Table No. 4.

ORE B. DATA ON ROASTS.

Roast No.	Mesh.	Max. Temp. Centegrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron		Percent of Zinc lost in Raosting.
				Raw	Roast	Raw	Roast	Raw	Roast	
1	2% 100–8mesh 2.36 mm	850°	1.25	34.75	20.45	54.3	59.6	6.0	6.3	0.0
2	2.5%-100 1 m.m.	864°	1.58	34.75	6.22	54.3	62.3	6.0	7.1	1.67

Table No. 5.

ORE B. TIME ROASTS.

Roast No.	Mesh.	Max. Temp. Centegrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron	
				Raw	Roast	Raw	Roast	Raw	Roast
1a	1.2% 100 1 m.m.	608°	4	34.75	28.12	54.3	55.5	6.0	6.6
1b	1.2%-100 1 m.m.	608°	6	34.75	26.15	54.3	54.2	6.0	7.2
1c	1.2%-100 1 m.m.	608°	8	34.75	27.27	54.3	55.4	6.0	6.6
1d	1.2%-100 1 m.m.	608°	10	34.75	26.55	54.3	55.6	6.0	6.4
2a	7%-100-10	710°	2	34.75	23.4	54.3	57.6	6.0	7.4
2b	7%-100-10	877°	4	34.75	5.1	54.3	63.0	6.0	8.2
2c	7%-100-10	916°	6	34.75	0.81	54.3	64.0	6.0	7.2
2d	7%-100-10	916°	8	34.75	0.52	54.3	64.6	6.0	7.9
3a	8.3%-100-8	982°	2	34.75	19.9	54.3	60.00	6.0	6.6
3b	8.3%-100-8	982°	4	34.75	8.18	54.3	62.7	6.0	7.0
3c	8.3%-100-8	982°	6	34.75	1.07	54.3	64.3	6.0	7.3
3d	8.3%-100-8	982°	8	34.75	0.48	54.3	64.0	6.0	7.2

Table No. 6.

ORE C. DATA ON ROASTS.

Roast No.	Mesh.	Max. Temp. Centegrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron		Percent of Zinc lost in Roasting.
				Raw	Roast	Raw	Roast	Raw	Roast	
1	39%-100-20 mesh	864°	1.83	33.3	7.08	54.2	62.6	5.4	5.0	1.5
2a	31%-100	956°	2	33.3	5.0	54.2	64.5	5.4	5.4	—
2b	31%-100	956°	4	33.3	0.69	54.2	65.8	5.4	5.4	—
2c	31%-100	956°	6	33.3	0.52	54.2	65.5	5.4	5.6	—
2d	31%-100	956°	8	33.3	0.48	54.2	65.3	5.4	5.6	—

Table No. 7.

ORE D. DATA ON ROASTS.

Roast No.	Mesh.	Max. Temp. Centegrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron		Percent of Zinc lost in Roasting.
				Raw	Roast	Raw	Roast	Raw	Roast	
1	30.8%-100 1.65 m.m.	764°	1.16	37.08	4.38	20.5	26.4	23.0	26 9	0.64
2	22%-100-8	780°	1.83	37.08	8.83	20.5	25.4	23.0	27.9	0.0

Table No. 8.

ORE D. TIME ROASTS.

Roast No.	Mesh.	Max. Temp. Centigrade	Time in Hours.	Percent Sulphur		Percent Zinc			Percent Iron	
				Raw	Roast	Raw	Roast Total	Roast Water Soluble	Raw	Roast
1a	5.2%-100-16 1 m.m.	500°	4	37.08	15.16	20.5	26.5	2.09	23.0	27.2
1b	5.2% 100-16 1 m.m.	500°	6	37.08	15.11	20.5	24.5	2.50	23.0	26.8
1c	5.2%-100-16 1 m.m.	500°	8	37.08	14.68	20.5	26.0	2.95	23.0	26.4
1d	5.2%-100-16 1 m.m.	500°	10	37.08	15.34	20.5	26.0	2.90	23.0	26.0
2a	19.5-100-10	764°	2	37.08	24.68	20.5	25.6	0.25	23.0	27.7
2b	19.5-100-10	848°	4	37.08	8.78	20.5	27.0	1.50	23.0	29.7
2c	19.5-100-10	872°	6	37.08	3.93	20.5	26.0	3.40	23.0	29.8
2d	19.5-100-10	872°	8	37.08	3.61	20.5	25.3	4.60	23.0	27.9
3a	37.6-100-20	—	4	37.08		20.5	26.4		23.0	24.8
3b	37.6-100-20	—	6	37.08		20.5	25.9		23.0	24.2
4a	37.6-100-20	—	4	37.08		20.5	25.6		23.0	24.0
4b	37.6-100-20	—	6	37.08		20.5	24.5		23.0	23.0

Table No. 9.

ORE E. DATA ON ROAST.

Roast No.	Mesh.	Max. Temp. Centigrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron		Percent of Zinc lost in Roasting.
				Raw	Roast	Raw	Roast	Raw	Roast	
1	12%-100 8	828°	1.67	11 38	1.49	51.9	58.8	0 8	0.8	2.90

Table No. 10.

ORE F. DATA ON CALCINATION.

Roast No.	Mesh.	Max. Temp. Centigrade.	Time in Hours.	Percent Sulphur		Percent Zinc		Percent Iron		Percent of Zinc lost in Roasting.
				Raw	Roast	Raw	Roast	Raw	Roast	
1	-100	600-700°	0.5	—	—	44.06	49.8	4.0	—	0.5
2	-100	824°	1.5	—	—	44.06	48.2	4.0	4.7	3.10

III. Leaching of the ore

The idea was to determine the maximum percentage of zinc that could be leached from the ores under the most favorable conditions.

The extractions obtained show what is possible under ideal rather than commercial conditions. Whether or not these extractions can be duplicated on a commercial scale, the writer cannot say, but under favorable conditions it seems that they should be duplicated fairly well.

The apparatus used for leaching was as follows: An ordinary pulp balance was used to weigh the charges and residues. The fifty-gram leaches were made in two-liter acid bottles. The 500-gram leaches were made in eight-liter acid bottles. The agitation was performed on a roll table, the bottles being turned completely over once every second. A Burchner funnel and suction pump were used for the filtration.

The method of procedure used in leaching was as follows: Fifty-gram samples were weighed out on the pulp balance and placed in two liter acid bottles. The exact amount of acid solution was calculated and added. The bottles were sealed with sealing wax and placed on the roll table for agitation. After the ore and solution had been agitated a sufficient length of time the bottles were removed and the solution filtered from the residue. The Burchner funnel and suction pump gave good results except on the high silica ores, which were difficult to filter. The residue was dried and the filter paper burned off. The residue was then sampled and analyzed.

The zinc in the residue and leach liquor was required to check the zinc in the heads within 2%.

Dilute sulfuric acid solutions were used for all the leaches. After solutions of various strengths had been tried, it was decided that a 10 per cent one was best, as it gave the zinc concentration desired for the electrolytic cells and decreased the bulk of solution to be handled. A more dilute solution gave the same extractions, but it had the disadvantage of giving an electrolyte low in zinc and a large volume to be handled. Very little work was done with stronger solutions, as they did not give promising results.

The first series of leaches were agitated for twenty-one hours. The idea was to extract all the zinc possible. The time given was considered sufficient for this, and later was found to be much in excess of the time required.

Leaches were made with the ore ground to pass a 100-mesh screen. It was thought that at 100-mesh all the zinc soluble would be exposed to the action of the acid. The results of these leaches and the leaches made with the ore as it came from the roaster did not show very much difference in zinc extraction. The ore appeared to have been rendered porous enough by roasting for the acid to penetrate it and extract all the soluble zinc. Where any added extraction did show as a result of grinding the ore, it was insufficient to pay for the cost of grinding.

The leaches were made at room temperature. One series was made at a very low temperature, as after an extremely cold night the solution was found partly frozen in the bottles. All the water seemed to be frozen, the remaining solution being concentrated sulfuric acid and zinc sulfate. The leaches were finished in the regular manner and checks run under ordinary conditions. The results of the checks agreed with the first results. This can be explained by the fact that the leaching was probably completed before the room dropped to the low temperature required to freeze the solution. The temperature must have dropped at least to 10° F. Ordinary tmperatures seem to be satisfactory for leaching.

The results of the leaches on the several ores are shown in the following tables:

Table No. 11.

(For the corresponding roasts see tables 2 and 3.)

ORE A. DATA ON LEACHES.

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution				Grams Zinc			Grams Iron		
						Percent Excess.	No. of cc.	Percent Strength.	Grams Used.	Heads.	Residue.	Percent Extracted.	Heads.	Residue.	Percent Extracted.
1	52%-100	1	50	13.77	21	15	1010	5	50.5	29.1	4.61	84.15	2.50	2.22	11.20
1	52%-100	2	50	13.79	21	15	505	10	50.5	29.1	4.51	84.50	2.50	1.93	22.80
1	52%-100	3	50	14.18	21	20	1053	5	52.7	29.1	4.79	83.54	2.50	2.17	13.2
1	52%-100	4	50	13.50	21	20	526	10	52.6	29.1	4.50	84.53	2.50	1.93	22.8
1	-100	5	50	14.22	21	15	1010	5	50.5	29.1	4.76	83.26	2.50	2.16	13.6
1	-100	6	50	14.86	21	15	505	10	50.5	29.1	5.50	81.09	2.50	2.32	7.2
1	-100	7	50	14.65	21	20	1053	5	52.7	29.1	5.04	82.68	2.50	2.30	8.0
1	-100	8	50	13.34	21	20	526	10	52.6	29.1	4.25	85.39	2.50	2.03	18.8
1	52%-100	9	50	14.50	23	10	967	5	48.3	29.1	5.10	82.4	2.50	2.23	10.8

ORE A. DATA ON LEACHES.—(Continued).

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution				Grams Zinc			Grams Iron		
						Percent Excess.	No. of cc.	Percent Strength.	Grams Used.	Heads.	Residue.	Percent Extracted.	Heads.	Residue.	Percent Extracted.
1	52%-100	10	50	14.74	23	20	1054	5	52.7	29.1	5.11	82.4	2.50	2.17	13.2
1	52%-100	11	50	13.88	23	10	483	10	48.3	29.1	4.66	84.0	2.50	2.12	15.2
1	52%-100	12	50	14.25	23	20	527	10	52.7	29.1	5.07	82.5	2.50	2.32	7.2
1	52%-100	13	50	15.14	1	0	879	5	43.95	29.1	5.19	82.16	2.50	2.24	10.4
1	52%-100	14	50	14.67	4	0	879	5	43.95	29.1	5.33	81.68	2.50	2.16	13.6
1	52%-100	15	50	14.73	8	0	879	5	43.95	29.1	5.21	82.10	2.50	2.16	13.6
1	52%-100	16	50	14.27	12	0	879	5	43.95	29.1	4.99	82.85	2.50	2.13	14.8
1	52%-100	17	50	14.71	16	0	879	5	43.95	29.1	5.02	82.75	2.50	2.18	12.8
1	52%-100	18	50	14.65	16	0	879	5	43.95	29.1	4.98	82.88	2.50	2.17	13.2
2	53%-100	19	50	8.84	21	0	940	5	47.0	30.2	1.15	96.1	2.55	1.94	23.9
2	53%-100	20	50	10.25	21	0	470	10	47.0	30.2	1.48	95.1	2.55	2.35	7.84
2	53%-100	21	50	8.28	21	10	1034	5	51.7	30.2	1.20	96.0	2.55	2.02	20.7
2	53% 100	22	50	15.87	21	10	517	10	51.7	30.2	3.97	86.8	2.55	2.03	20.3
2	-100	23	50	8.29	21	0	940	5	47.0	30.2	1.04	96.5	2.55	1.99	21.9
2	100	24	50	9.40	21	0	470	10	47.0	30.2	1.34	95.52	2.55		
2	100	25	50	8.79	21	10	1034	5	51.7	30.2	1.16	96.1	2.55	2.34	8.23
2	-100	26	50	13.00	21	10	517	10	51.7	30.2	2.98	90.1	2.55	2.16	15.2
3	67% 100	27	50	7.83	21	0	914	5	45.67	29.65	1.22	95.8	2.30	2.25	2.17
3	67%-100	28	50	8.60	21	0	457	10	45.67	29.65	1.41	95.2	2.30	2.25	2.17
3	67%-100	29	50	7.98	21	10	1004	5	50.23	29.65	1.38	95.3	2.30	2.19	4.78
3	67%-100	30	50	8.10	21	10	502	10	50.2	29.65	1.42	95.2	2.30	2.19	4.78
3	-100	31	50	8.13	21	0	914	5	45.67	29.65	1.37	95.3	2.30	2.25	2.17
3	-100	32	50	8.14	21	10	1004	5	50.23	29.65	1.34	95.4	2.30	2.29	0.4
3	100	33	50	15.90	18	0	457	10	45.7	29.65	4.85	80.36	2.30		
4	65%-100	34	50	7.20	21	0	954	5	47.7	30.3	1.39	95.4	2.60	1.59	38.8
4	65%-100	35	100	29.9	21	0	954	10	95.4	60.6	7.36	87.8	5.20	4.10	21.1
4	65%-100	36	50	4.8	21	10	1049	5	52.45	30.3	0.60	98.01	2.60	1.21	53.4
4	65%-100	37	50	5.0	21	10	525	10	52.5	30.3	0.62	97.95	2.60	1.20	53.84
4	-100	38	25	3.42	21	0	477	5	23.89	15.15	2.83	98.8	1.30	0.98	24.6
4	-100	39	50	7.58	21	0	477	10	47.7	30.3	1.13	96.2	2.60	2.18	16.1
4	-100	40	25	3.22	21	10	525	5	23.25	15.15	0.52	96.5	1.30	0.85	24.6
4	100	41	50	7.85	21	10	525	10	52.5	30.3	1.37	95.4	2.60	2.29	11.9
5	67.2%-100	42	50	8.80	20	0	892	5	44.6	29.5	1.72	94.17	2.50	2.06	17.6
5	67.2%-100	43	500	91.0	8.5	0	8924	5	446.2	295.5	16.29	94.48	2.50	20.93	16.28
1a	39%-100	44	50	21.02	6	0	384	10	38.4	25.4	10.22	59.76	2.20	1.10	50.0
1b	39%-100	45	50	12.23	6	0	367	10	33.7	24.3	4.42	81.81	2.00	1.38	31.0
1c	39%-100	46	50	11.03	6	0	367	10	36.7	24.3	3.73	84.65	2.05	1.31	36.09
1d	39%-100	47	50	10.03	6	0	363	10	36.3	24.05	3.09	87.15	1.85	1.31	29.18
2a	40%-100	48	50	19.60	4	10	473	10	47.3	28.45	8.96	61.47	2.55	1.72	32.55
2b	40%-100	49	50	10.0	4	10	484	10	48.4	29.1	2.0	93.12	2.65	2.24	15.47
2c	40%-100	50	50	14.13	4	10	487	10	48.7	29.3	3.77	87.13	2.70	2.46	8.88
2d	40%-100	51	50	9.20	4	10	492	10	49.2	29.6	1.10	96.30	2.65	2.59	2.26
3d	42%-100	52	50	7.87	4	10	513	10	51.3	30.90	1.33	95.69	2.60	2.37	8.84
4a	60.7%-100	53	50	38.55	4	10	444	10	44.4	26.75	21.09	21.19	2.10	1.62	22.7
4b	60.7%-100	54	50	27.48	4	10	450	10	45.0	27.10	14.21	48.26	2.30	1.25	45.65
4c	60.7%-100	55	50	32.18	4	10	418	10	41.8	27.65	17.38	37.14			

Table No. 12.

(For the corresponding roasts see tables 4 and 5.)

ORE B.

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution				Grams Zinc			Grams Iron		
						Percent Excess.	No. of cc.	Percent Strength.	Grams Used.	Heads.	Residue.	Percent Extracted.	Heads.	Residue.	Percent Extracted.
1	2%-100-8	1	50	40.75	23	0	874	5	43.7	29.8	19.07	36.0			
1	2%-100-8	2	50	37.26	23	10	962	5	48.1	29.8	19.49	34.6			
1	2%-100-8	3	50	37.57	23	0	437	10	43.7	29.8	20.06	32.7			
1	2%-100-8	4	50	37.95	23	10	480	10	48.0	29.8	19.28	35.3			
1	2%-100-8	5	50	39.50	23	0	874	5	43.7	29.8	19.55	34.39			
1	2%-100-8	6	50	36.80	23	10	962	5	48.1	29.8	18.80	36.91			
1	2%-100-8	7	50	39.72	23	0	437	10	43.7	29.8	19.22	35.5			
1	2%-100-8	8	50	39.56	23	10	480	10	48.0	29.8	18.63	37.48			
1	-100	9	50	27.91	21	0	874	5	43.7	29.8	13.0	56.37			
1	-100	10	50	27.83	21	10	962	5	48.1	29.8	13.38	55.10			
1	-100	11	50	39.43	21	0	437	10	43.7	29.8	21.49	27.9			
1	-100	12	50	43.62	21	10	480	10	48.0	29.8	24.51	17.75			
2	2.5%-100-16	13	50	21.24	4	0	940	5	47.0	31.15	6.48	79.19			
2	2.5%-100-16	14	50	22.12	8	0	940	5	47.0	31.15	6.79	78.20			
2	2.5%-100-16	15	50	18.82	12	0	940	5	47.0	31.15	6.91	77.81			
2	2.5%-100-16	16	50	16.44	16	0	940	5	47.0	31.15	6.07	80.51			
2	2.5%-100-16	17	50	17.17	21	0	910	5	47.0	31.15	6.13	80.32			
2	2.5%-100-16	18	500	175.2	21	0	9407	5	470.3	311.5	67.10	78.45			
1a.	12%-100-16	19	50	45.39	6	0	419	10	41.9	27.75	25.60	7.78	3.30	2.85	13.63
1b	1.2%-100-16	20	50	42.62	6	0	409	10	40.9	27.10	23.95	11.62	3.60	2.73	24.16
1c	1.2%-100-16	21	50	42.85	6	0	418	10	41.8	27.70	23.91	13.68	3.30	2.82	14.54
1d	1.2% 100-16	22	50	42.65	6	0	420	10	42.0	27.80	23.71	14.71	3.20	2.77	13.43
2a	7%-100-10	23	50	37.14	4	10	479	10	47.9	23.8	20.61	23.43	3.70	2.90	21.62
2b	7%-100-10	24	50	20.83	4	10	523	10	52.3	31.5	8.94	71.61	4.20	3.23	23.09
2c	7%-100-10	25	50	10.86	4	10	532	10	53.2	32.0	2.49	92.22	3.60	3.44	4.44
2d	7%-100-10	26	50	10.00	4	10	537	10	53.7	32.3	1.47	95.44	3.90	3.29	15.64
3a	8.3%-100-8	27	50	36.69	4	10	498	10	49.8	30.0	16.92	42.93	3.30	3.08	6.66
3b	8.3%-100-8	28	50	20.5	4	10	521	10	52.1	31.35	9.16	70.81	3.50	3.50	0.00
3d	8.3%-100-8	29	50	9.98	4	10	532	10	53.2	32.0	1.41	95.60	3.60	3.59	0.0

Table No. 13.

(For the corresponding roasts see table 6.)

ORE C.

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution				Grams Zinc			Grams Iron		
						Percent Excess.	No. of cc	Percent Streng	Grams Used.	Heads.	Residue.	Percent Extracted.	Heads.	Residue.	Percent Extracted.
1	39%-100-20	1	50	19.69	23	0	959	5	47.95	31.3	8.53	72.7			
1	39%-100-20	2	50	17.20	23	10	1054	5	52.7	31.3	7.31	76.6			
1	39%-100-20	3	50	17.65	23	0	479	10	47.9	31.3	7.36	76.4			
1	39%-100-20	4	50	16.99	23	10	527	10	52.7	31.3	7.12	77.2			
1	39%-100-20	5	50	17.86	23	0	959	5	47.9	31.3	6.91	77.9			
1	39%-100-20	6	50	16.54	23	10	1054	5	52.7	31.3	6.70	78.5			
1	39%-100-20	7*	50	31.49	23	0	479	10	47.9	31.3	16.19	48.2			
1	39%-100-20	8	50	13.88	23	10	527	10	52.7	31.3	5.04	83.9			
1c	31%-100-100	9	50	6.81	4	10	544	10	54.4	32.75	1.47	95.51	2.80	2.34	16.43
1d	31%-100-100	10	50	6.93	4	10	542	10	54.2	32.65	1.28	96.07	2.80	2.49	11.07

Table No. 14.

(For the corresponding roasts see tables 7 and 8.)

ORE D.

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution Percent Excess.	 No. of cc.	 Percent Strength.	 Grams Used.	Grams Zinc Heads.	 Residue.	 Percent Extracted.	Grams Iron Heads.	 Residue.	 Percent Extracted.
1	30.8%-100-10	1	50	37.17	21	20	458	5	22.9	13.20	3.75	71.59	11.50		
1	30.8%-100-10	2	50	36.57	21	20	229	10	22.9	13.20	4.10	69.0	11.50		
1	30.8%-100-10	3	50	35.84	21	10	438	5	21.9	13.20	4.19	68.25	11.50		
1	30.8%-100-10	4	50	36.27	21	10	219	10	21.9	13.20	4.06	69.24	11.50	11.42	0.69
1	-100	5	50	34.39	21	20	458	5	22.9	13.20	4.22	68.03	11.50	11.48	0.16
1	-100	6	50	34.40	21	20	229	10	22.9	13.20	4.44	66.36	11.50		
1	-100	7	50	34.53	21	10	438	5	21.9	13.20	4.42	66.51	11.50		
1	-100	8	45	31.56	21	10	179	10	17.9	11.88	3.88	67.34	10.35	10.35	0.0
2	22%-100-8	9	50	39.20	21	0	192	10	19.2	12.70	7.53	40.7	13.95	12.35	11.40
2	22%-100-8	10	50	38.35	21	10	211	10	21.1	12.70	7.21	43.2	13.95	12.35	11.40
2	22%-100-8	11	50	39.15	21	20	230	10	23.0	12.70	7.48	41.1	13.95	12.33	11.60
2	22%-100-8	12	50	38.98	21	30	250	10	25.0	12.70	7.13	43.8	13.95	12.63	9.40
2	-100	13	50	39.58	21	0	192	10	19.2	12.70	6.53	48.58	13.95	13.93	0.13
2	-100	14	50	39.85	21	0	382	5	19.1	12.70	6.73	47.00	13.95	13.95	0.0
2	-100	15	50	39.44	21	For Fe'''	274	10	27.4	12.70	8.80	30.7	13.95	11.91	14.6
2	-100	16	50	39.18	21	For Fe'''	548	5	27.4	12.70	8.03	36.7	13.95	12.34	11.5
1a	52%-100-16	17	50	44.89	6	0	200	10	20.0	13.25	11.76	11.24	13.60	12.12	10.89
1b	52%-100-16	18	50	44.35	6	0	185	10	18.5	12.25	12.25	0.0	13.40	11.71	12.61
1c	52%-100-16	19	50	44.07	6	0	176	10	17.6	13.0	12.30	5.39	13.20	11.55	12.50
1d	52%-100-16	20	50	43.81	6	0	176	10	17.6	13.0	12.49	3.92	13.00	11.00	15.38
3a	37.6%-100-20	25	50	36.70	18		250	10	25.0	13.2	5.51	58.25	12.4	11.60	6.45
3b	37.6%-100-20	26	50	33.40	18		250	10	25.0	12.95	3.17	75.52	12.1	11.82	1.65
4a	37.6%-100-20	27	50	35.55	18		250	10	25.0	12.80	4.23	66.95	12.0	11.60	3.33
4b	37.6%-100-20	28	50	38.45	18		250	10	25.0	12.25	2.68	77.96	11.50	11.70	

Table No. 15.

(For the corresponding roast see table 9.)

ORE E.

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution Percent Excess.	 No. of cc.	 Percent Strength.	 Grams Used.	Grams Zinc Heads.	 Residue.	 Percent Extracted.	Grams Iron Heads.	 Residue.	 Percent Extracted.
1	12%-100-8	1	50	17.82	20	0	888	5	44.4	29.4	3.14	89.32	0.4	0.18	55.0
1	12%-100-8	2	50	8.60	20	10	977	5	48.8	29.4	1.33	95.47	0.4	0.19	52.5
1	12%-100-8	3	50	8.45	20	20	1066	5	53.3	29.4	1.44	95.10	0.4	0.20	50.0
1	12%-100-8	4	50	17.93	20	0	444	10	44.4	29.4	3.16	89.25	0.4	0.18	55.0
1	12%-100-8	5	50	8.40	20	10	489	10	48.9	29.4	1.33	95.47	0.4	0.17	57.5
1	12%-100-8	6	50	7.70	20	20	533	10	53.3	29.4	1.08	96.3	0.4	0.18	55.0

Table No. 16.
(For the corresponding roast see table 10.)

ORE F.

Roast No.	Thru Mesh.	Leach No.	Heads Weight.	Residue Weight.	Time of Agitation in Hours.	Acid Solution				Grams Zinc			Grams Iron		
						Percent Excess.	No. of cc.	Percent Strength.	Grams Used.	Heads.	Residue.	Percent Extracted.	Heads.	Residue.	Percent Extracted.
1	-100	1	50	34.28	21	0	712	5	35.6	24.90	8.54	65.70			
2	-100	2	50	31.76	21	0	728	5	36.39	24.10	7.72	67.96	2.35	1.62	31.06
2	-100	3	50	37.35	21	0	364	10	36.4	24.10	8.48	64.81	2.35	1.64	30.21
2	-100	4	50	32.58	21	10	800	5	40.0	24.10	7.33	69.58	2.35	1.76	25.10
2	-100	5	50	10.15	21	10	400	10	40.0	24 10	0.96	96.01	2.35	1.36	42.12

IV. Purification of the solution

The most important step in the electrolytic zinc process appears to be the purification of the solution. Research work has been carried on for a number of years on the electrodeposition of zinc from solutions obtained. Until recently all of the processes attempted to deposit the zinc from impure leaching solutions, and were failures. Now, however, by using practically the same process, but purifying the solution for electrolysis, favorable results have been attained and large commercial plants have been erected.

It appears that an absolutely pure solution is essential for successful electrolysis. The presence of some impurities, though in very small proportions, will not only give an impure deposit, but will prevent the deposition of zinc in a smooth, coherent deposit.

The chemistry of the purification of the solution for electrolysis is given in the next paragraphs.

The solution from the leaches contains the following impurities: Arsenic, antimony, iron, manganese, copper, and cadmium, together with various others of less importance.

The iron is the first impurity to be removed. It is present mostly in the ferrous state and must be oxidized to the ferric condition before it can be precipitated and removed as ferric hydroxide. Various oxidizing agents can be used. Manganese dioxide is generally added to oxidize the iron. The oxidization takes place according to the following reaction:

$$2FeSO_4 + MnO_2 + 2H_2SO_4 \rightarrow Fe_2(SO_4)_3 + MnSO_4 + 2H_2O$$

The free acid in the solution must be neutralized before the iron can be precipitated as the hydroxide. Limestone, milk of lime, high-grade roasted zinc ore, or zinc oxide can be used to neutralize the free acid and precipitate the iron. The method of leaching can be so arranged as to run the solution through a fresh charge of

ore. This will use up the free acid, while the ferric hydroxide will be precipitated from the solution when it becomes slightly alkaline. When milk of lime is used the following reaction takes place:
$3Fe_2(SO_4)_3 + 9Ca(OH)_2 + 18H_2O \rightarrow 6Fe(OH)_3 + 9CaSO_4 \cdot 2H_2O$

The insoluble ferric hydroxide is precipitated, and carries down with it the arsenic and antimony present. The freshly precipitated ferric hydroxide forms an insoluble compound with arsenious oxide and carries it out of the solution. The antimony acts in a similar manner. The solution contains copper, cadmium and similar metals, and these are removed with some form of metallic zinc. Some of the metals are replaced by zinc as shown by the following reactions:

$$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$$
$$Zn + CdSO_4 \rightarrow Cd + ZnSO_4$$

The filtered solution should be sufficiently pure for the electrolytic cells.

The method of procedure follows:

The iron was oxidized in three ways: (1) By forcing air through the solution; (2) By passing ozone through the solution; (3) By addition of manganese dioxide.

(1) Compressed air was passed through the solution for some time, and the remainder of the purification carried out in the regular manner.

(2) Ozone was passed through the solution slowly. Considerable difficulty was experienced in handling the ozone. The machine was rather small and the work was carried on under difficulties. The results cannot be taken as final. Ozone is a cheap and efficient oxidizing agent, and when properly applied, it seems that it should prove the cheapest and most effective method of oxidizing the iron in solutions free from manganese.

(3) Manganese dioxide was added to the solution and thoroughly agitated with compressed air. This gave very satisfactory results.

The solution was filtered. The copper, cadmium, and similar metals were precipitated from the solution by means of zinc dust. The zinc dust was added to the solution and thoroughly agitated. Better results were obtained when the solution was allowed to drop slowly through a filter containing zinc dust. It is thought that this was due to the greater length of time the solution was in contact with the zinc. Zinc scraps and shavings have been used to remove copper, etc., but zinc dust has been found to be the most speedy and efficient reagent for this purpose.

The solution was then filtered to remove the excess zinc dust and the metals which were thrown out of solution. The filtered solution should be pure enough for the electrolytic cells.

V. Electro-deposition of zinc from zinc sulfate solutions.

The electro-deposition of zinc has been studied for a long time, but until purified solutions were used for electrolysis the results were always failures. When purified solutions were used, favorable results were obtianed, and fairly smooth, dense, coherent deposits of zinc became a possibility. The best conditions for obtaining good deposits of zinc are not yet settled, but the progress being made in this branch of the art is very rapid.

The electro-deposition of zinc from purified leaching liquors requires an insoluble anode. When insoluble anodes are used, numerous difficulties are encountered which are not encountered when soluble anodes are used, as in the refining processes. A soluble anode goes into solution at about the same rate as the metal is deposited from solution. The concentration of the electrolyte is therefore nearly constant. There is a no counter-electromotive to overcome when soluble anodes are used, for the electromotive force of solution is equal and opposite to the electromotive force of decomposition. Therefore, a lower voltage can be used with soluble anodes.

The insoluble anode presents the following difficulties: The concentration of the electrolyte is varying continually as electrolysis takes place; the solution is becoming depleted in zinc and the harmful impurities are gaining in quantity relative to the zinc: when the zinc concentration falls below a certain value the zinc no longer deposits in a smooth, coherent plate. The impurities must be watched so they do not concentrate beyond the value at which they are detrimental to good working conditions. With insoluble anodes more power must be used to overcome the counter-electromotive force.

Lead is employed for the insoluble anodes in the processes now in use. Lead is fairly insoluble in dilute sulfuric acid, and during electrolysis the anode is covered with a coating of lead peroxide which renders it more insoluble.

Carbon has been used for the anode, but does not give as good results as the lead. There are a number of other materials that appear to be fitted for anodes.[5]

Aluminum cathodes are used generally. Zinc starting-sheets have been employed, but sheets of aluminum are given the preference. Zinc deposits very readily on a clean aluminum cathode and is very easily removed. The zinc deposit is stripped from the aluminum cathode with a cold chisel, leaving a clean, smooth plate, which is returned to the cell and used repeatedly. This saves the expense of making zinc starting-sheets and the time and labor of replacing the cathodes in the cells every forty-eight hours as is required when zinc starting-sheets are used. The aluminum cathode appears to be much more economical than zinc starting-sheets.

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[5] "Metallurgical and Chemical Engineering," Feb. 1, 1917.

The electrolyte was a purified zinc sulfate solution which resulted from leaching zinc ores. It contained around 6 per cent of zinc when run into the cell for electrolysis. The percentage of free sulfuric acid in the solution was regulated as desired.

The electrolytic cell.—The cell was made of a small battery jar with an overflow arranged to keep the surface of the solution at a constant level. The lead anodes were cut from sheet lead one-eighth of an inch thick and hung from copper bus bars. The aluminum cathodes were cut from sheet aluminum one-tenth of an inch thick and hung from copper bus bars.

The electrolyte was agitated with compressed air in one series of experiments. The air was passed into the solution through a perforated glass tube, which lay on the bottom of the cell between the anode and cathode. The electrolyte was circulated through the cell by gravity, in another series of experiments in the following manner:

The reservoir containing the solution was elevated slightly above the electrolytic cell so that the solution would flow gradually to it. An overflow kept the solution at a constant level in the cell, and the solution from the overflow ran to a jar at a lower level. When the reservoir was emptied, it was refilled with the solution from the overflow jar and the solution again ran through the cell. This was repeated until the zinc content of the solution reached a low figure.

The method of procedure was as follows: The solution was run into the cell and the current turned on. The voltage and amperage were regulated to meet the conditions required for electrolysis. The electrolysis was continued until the zinc concentration of the electrolyte became low, or until the deposit grew bad. The electrolyte was agitated, (1) with compressed air, (2) by circulating it through the cell by gravity, (3) by stirring with a stirring rod. At night it received no stirring. Practically no circulation or agitation was given to these tests.

The solution was electrolyzed at room temperature. A thermometer was kept in the cell to show any temperature rise during electrolysis.

A current density of twenty to thirty amperes per square foot of cathode surface was used. The voltage drop across the cell varied with the acidity of the electrolyte. About four volts were required to start the cell with a neutral solution. This voltage decreased as electrolysis proceeded and the solution became more and more acid. About 3.2 volts were required just before electrolysis was stopped.

The effects of some impurities are not clearly understood. Certain things take place when certain impurities are present.

Whether they alone or in combination cause the effects is not known. The effect of the following impurities will be given as far as known. The exact actions which take place are unknown:

Arsenic.—Arsenic must be completely removed from the electrolyte or it will prevent the deposition of zinc in a smooth, coherent deposit. Some metallurgists claim that a trace of arsenic will prevent the deposition of zinc. The quantity of arsenic necessary to ruin a deposit is very small. The statement is made that one part in a million is harmful.

Antimony.—The action of antimony is similar to arsenic and appears to be equally harmful.

Iron.—Ferrous iron in the electrolyte is harmful. It will be oxidized at the anode, and current is required for the action. It uses up current and may find its way into the cathode deposit and contaminate the zinc.

Ferric iron in the electrolyte in reasonable quantities is said to produce no harmful results, and it will increase the iron content of the cathode.

Manganese.—Manganese is present in nearly all western zinc ores. If it is not present in the ore, it has been found necessary to add it to oxidize the iron. Manganese is a beneficial impurity. Its action is to oxidize the iron and then be reoxidized in the electrolytic cell. When reoxidized, it is again available to oxidize the iron. Its chemistry has already been explained under the purification of the solution.

Copper.—Copper is detrimental to good deposits. The amount in the solution determines its action. Large amounts will deposit upon the cathode, then fall to the bottom of the cell in spongy form. Small amounts will cause black splotches on the cathode and prevent deposition. The presence of copper increases the tendency of zinc to deposit as dust or sponge. The amount of copper in the solution should be kept as small as possible.

Cadmium.—Cadmium will deposit out of a sulfate solution along with zinc. To produce a cadmium free cathode, the cadmium must be removed from the solution, as any cadmium in the electrolyte will show up in the cathode.

Cadmium in spelter has been the basis of much argument and more trouble. All buyers of spelter claim that very small percentages are injurious. For each different use to which the spelter is put, a different difficulty arises, at least according to spelter buyers. Many metallurgists have doubted the extreme evil effects claimed to be due to small percentages of cadmium, and some late work upon this subject shows very favorably in their behalf. Cadmium is a good excuse for penalty, therefore it should be kept as low as possible in the cathodes.

Addition agents.—It was planned to do considerable work on addition agents, but the time was too limited and very little was accomplished. This work is to be continued.

Glue was the only addition agent used. It seemed to improve the deposit considerably. In one instance it appeared to cause deposition from a solution which otherwise did not appear to deposit very readily. When carefully purified neutral solutions were used the deposit appeared as good without as with glue. This held also for slightly acid solutions.

The results upon the electro-deposition are few, because the greater part of the time was spent upon the roasting, leaching, and purification of the solution. The results which were obtained will be given in the following discussion. The difficulties encountered, due to impurities, have been explained under that heading.

Too high a current density gave a cathode which appeared to be oxidized. The electrolyte had been agitated with compressed air blown up between the electrodes, and this might account for the appearance of the cathode. When pure solutions were used the current density could be held very low and have good deposits result.

Deposits of sponge zinc were not obtained. Either a good deposit resulted, or the zinc started to deposit, blackened, and did not deposit further. Spongy zinc and similar troubles so often read about were not encountered.

The first tests were made using cathodes which had 36 sq. in. in active surface. This was soon reduced to 9 sq. in., as too much solution was required to obtain a deposit of any thickness.

The edges of the cathodes were rounded and made smooth in an attempt to eliminate edge sprouts, but this did not entirely prevent them. The edges of the cathodes were then covered with strips of wood, and edge sprouting was eliminated. Some soft coarse grained wood was used on one cathode, and sprouts grew through the coarse grains of the wood and short-circuited the cell. A hard, dense wood should be used and no end grain left exposed.

The zinc was deposited on one side of the cathode only, the other side being covered with some non-conducting material. Several non-conducting materials were tried before a satisfactory one was found. Asphalt varnish peeled from the plate before one series of tests were run. Paraffin adhered to the cathode fairly well, but peeled and fell from the anode. Sealing wax gave satisfactory results and was permanent. Care had to be used in applying it so that no fine blow holes would remain after it was cooled. If the blow holes remained, zinc trees built up from them very rapidly.

No remarkable or revolutionary discoveries have been made in this work, but it is hoped that by collecting and condensing some of the knowledge available on the electrometallurgy of zinc this paper will prove valuable. The tables show the results which can be expected to result from treating other similar ores. But it must be remembered that every ore is a separate and distinct problem and may require a special treatment.

The next number of the Technical Series of this Bulletin will comprise a Bibliography of Zinc Roasting, Leaching, Smelting, Electric Smelting and Electrolysis, compiled by the staff of the Library.

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Vol. 6, No. 4, Never published.

Vol. 7, No. 1, Never published.

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Vol. 3, No. 4, May, 1917. Studies in the production of oils and tars from bituminous materials. J. C. Ingram.

Vol. 4, No. 1, August, 1917. The hydrometallurgy and electrolytic precipitation of zinc. F. D. James.

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Volume Four Number Two

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

BULLETIN

NOVEMBER, 1917

TECHNICAL SERIES

THE EFFECT OF ADDITION AGENTS IN FLOTATION

ROLLA, MISSOURI

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SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

THE EFFECT OF ADDITION AGENTS IN FLOTATION

by

MARTIN HARMON THORNBERRY, B. S.,
Research Assistant,

and

HORACE THARP MANN, E. M.,
Associate Professor of Metallurgy and Ore Dressing.

PART I.
SULPHATES, HYDROXIDES AND NITRATES.

ROLLA, MISSOURI
1917

AUG 19 1918
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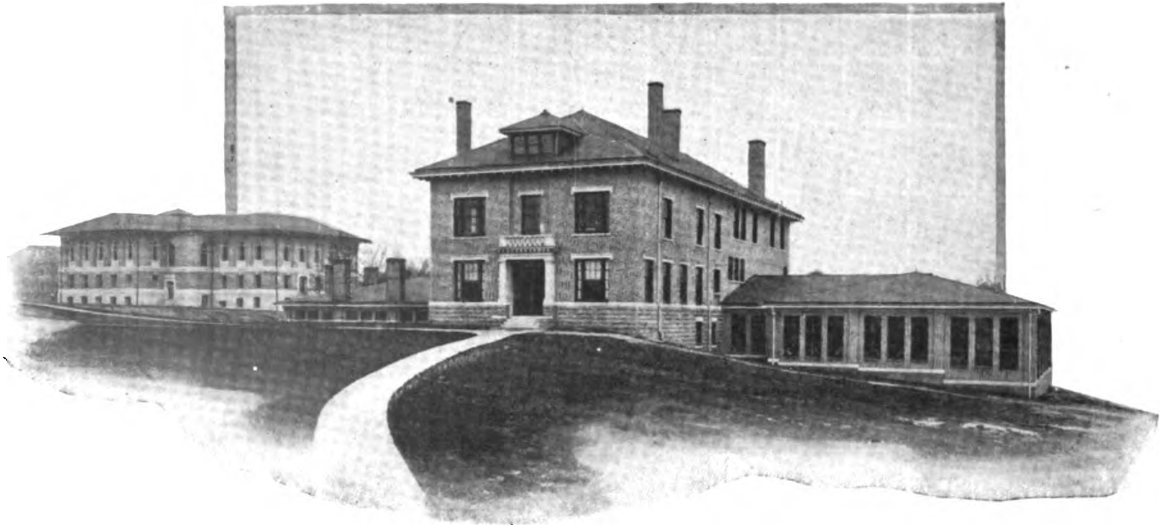

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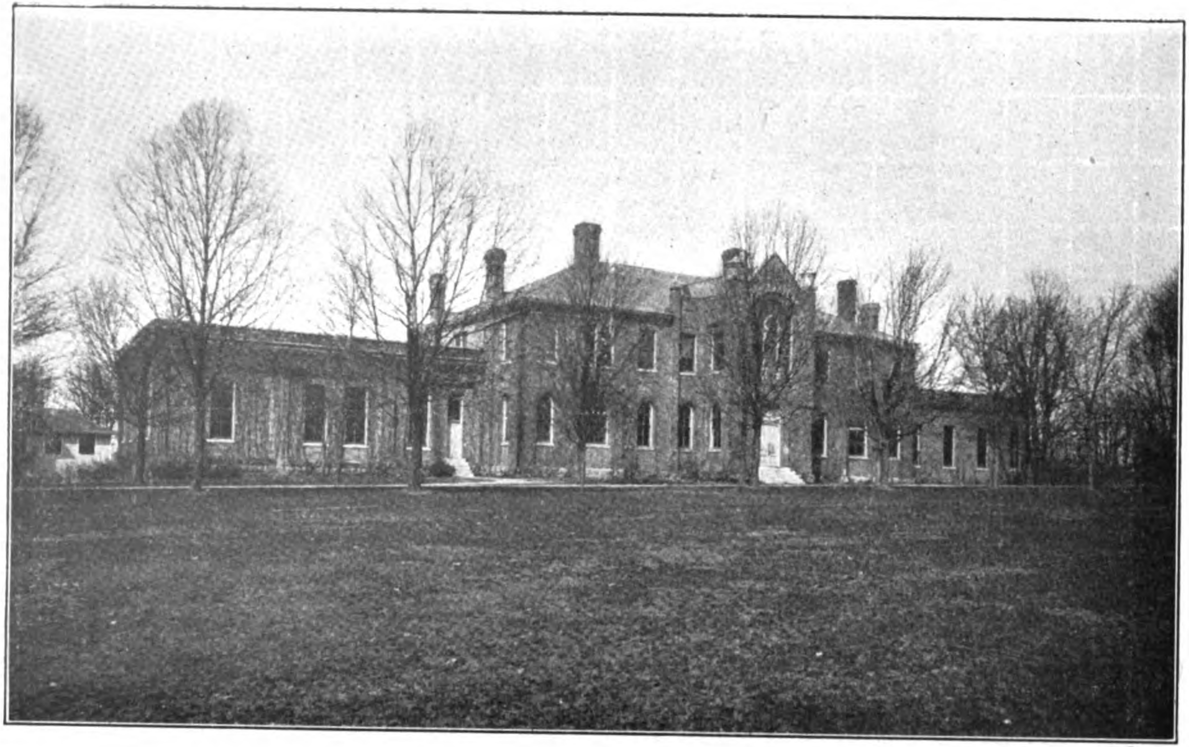


CHEMISTRY BUILDING

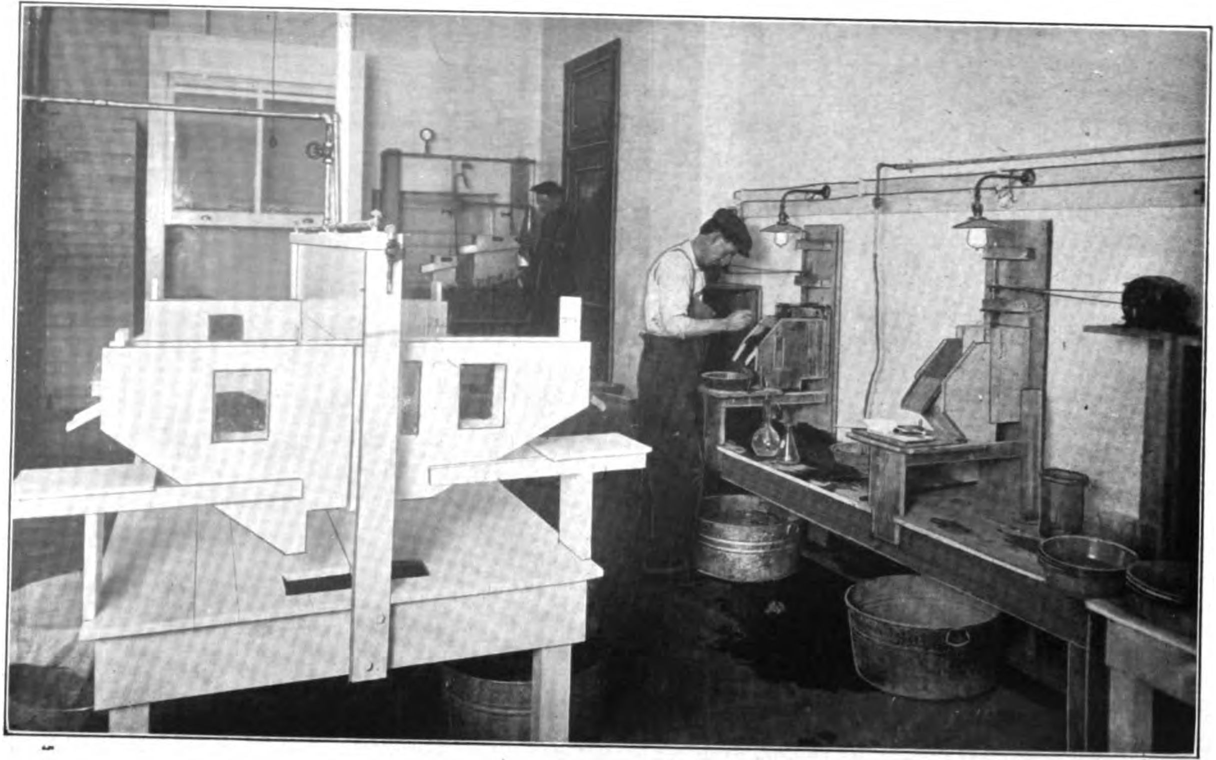
FOREWORD

Most of the material included in this Bulletin first appeared in *Metallurgical and Chemical Engineering.* The work has been carefully revised and is here reprinted in fuller and more extended form.

The authors are indebted to Dr. V. H. Gottschalk, Professor of Chemistry, for suggestions and encouragement during the progress of the work.

Mr. W. J. Mann did much of the experimental work. To him thanks are due for his care in carrying out each test.

Assistance was also rendered by the Cleveland Cliff Iron Company and the General Naval Stores Company, who very kindly contributed flotation oils for these tests.



FLOTATION LABORATORY

BULLETIN
OF THE
School of Mines and Metallurgy
UNIVERSITY OF MISSOURI
TECHNICAL SERIES

VOL. IV NOVEMBER, 1917 No. 2

THE EFFECT OF ADDITION AGENTS IN FLOTATION

In the great amount of literature published on the subject of flotation, including many articles by able technical men, descriptions of patents covering various flotation processes and data on many of the flotation installations throughout the country, are to be found numerous statements indicating that certain factors. such as slight acidity and alkalinity and the presence of small quantities of soluble salts, have shown marked influence upon the separation of the mineral from the gangue, or in the separation of one mineral from another. Our own experience has confirmed this frequent appearance of a preponderant influence of some wholly unexpected factor, and it is the object of the following investigations to obtain more exact data concerning one class of such factors, namely, the influence of the commoner inorganic salts.

The work as outlined covered tests on three ores: a lead ore from southeast Missouri, a zinc ore from southwest Missouri, and a mixed lead and zinc ore from southwest Missouri. Only a part of the work on the lead ore is reported at this time. However, the portion of the work on the zinc ore already completed is similar in its results, and these data will be published later.

Tests on Lead Slime

The lead ore used in the following experiments is a typical slime from the southeast Missouri lead district. The chemical analysis of one sample is as follows:

	Per Cent		Per Cent
Pb	4.64	Cu	0.00
Zn	0.30	CaO	22.68
Fe	3.51	MgO	13.11
S	3.57	Insoluble	16.68

The screen analysis of this material shows the following results:

	Mesh	Average Size of Opening, Mm.	Percentage	Per Cent, Lead
On	28	0.589	0.00	0.00
On	35	0.417	1.00	1.21
On	48	0.295	0.60	2.82
On	65	0.208	1.60	3.20
On	100	0.147	4.69	3.07
On	150	0.104	15.20	3.41
On	200	0.074	36.80	4.87
Through	200	....	40.20	6.14

Tyler standard screens were used and the material was shaken for 40 minutes on the Ro-Tap.

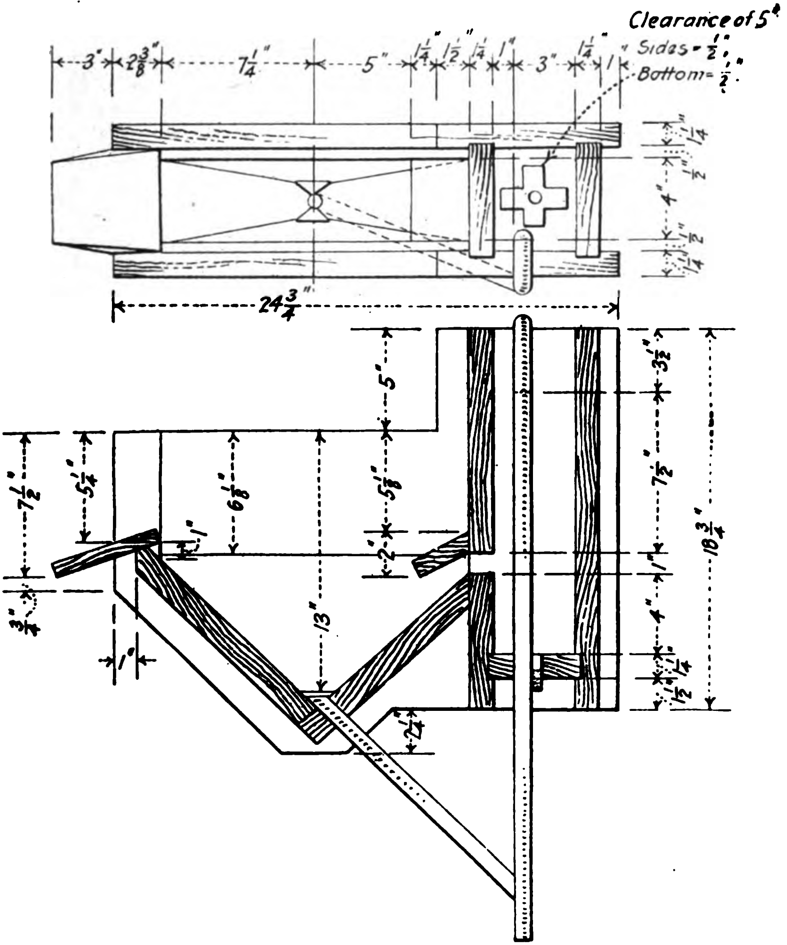
This slime was barreled wet and when received it contained from 10 per cent to 15 per cent moisture. The material was not dried, and, as our water supply has practically the same analysis as the water with the ore, tap water was used in the tests, since it was thought no advantage could be gained by the use of distilled water. The feed did not contain a constant percentage of lead in all experiments, but the variation was small, ranging from 4.30 per cent to 4.90 per cent lead. This is due to the fact that more than one barrel of pulp was used in these tests.

All solutions and emulsions contained 5 per cent of the salt by weight in water. The quantities used were 5 cc., 15 cc., 25 cc. and 50 cc. per charge of approximately 800 grams of dry ore. These quantities are equivalent to 0.625, 1.875, 3.125 and 6.25 lb. respectively of the salt per ton of dry ore.

Flotation Machine With Air-Lift

The machine used for this work was designed in the flotation laboratory and built in the school shops, and is a modified form of the Minerals Separation type machine as illustrated and described in the *Engineering and Mining Journal* of September 4, 1915.

It was found that the original machine did not have sufficient suction to keep either a charge of coarse ore or a charge of ore with a high sulphide content in circulation, hence the air-lift was substituted to overcome this difficulty. This particular type of machine, with all modifications, produces a concentrate having a higher metallic content than that produced in the original machine, due to the fact that it gives a greater area for froth and at the same time allows the froth to accumulate at a point where the currents due to the inflow of pulp from the agitation compartment have little effect. A drawing of the apparatus is shown on the opposite page.



FLOTATION MACHINE

Conditions of Experiments

Tests were first run on this ore with a large variety of oils, from which three were selected for this work. The results obtained from the use of each oil have been tabulated and plotted and may be found in accompanying tables and charts.

The method of conducting the experiments is as follows: The moisture was determined and a charge of wet pulp containing approximately 800 gm. of dry ore was weighed and poured into the machine with sufficient tap water to give the charge a dilution of 5 of water to 1 of dry ore by weight. The machine was started and the desired quantity of the reagent added. After a thorough mixing, a quantity of oil equivalent to 0.5 pound per ton of dry ore was added and the froth skimmed off as fast as it raised above the overflow of the machine. A bubble column of about two inches was carried until the very last of the experiment, when all froth was skimmed off. This practice undoubtedly both raises the extraction and lowers the grade of concentrate to some extent, but, as this procedure was uniform throughout, the results are comparable. The duration of the test was 40 to 45 minutes and the speed of the machine 1700 r. p. m.

All operating conditions, such as the speed of the impellor, duration of the test, volume of pulp in machine, etc. were kept as uniform as possible, but in so large a number of experiments variations were unavoidable. These would necessarily cause slight variations in the results obtained; but nearly every result in the charts has been checked once, and where there was a pronounced variation in either extraction or grade of concentrate, the results have been checked several times.

The numerals shown on the charts are the numbers of the various experiments, three being made without any addition agent and four each with a different addition agent. Those without addition agents numbered 1, 2, 3 and 0, the last showing the average results of the first three. The numbers of experiments with addition agents are given in the following paragraphs, four to each experiment, and indicate results obtained respectively with 5, 15, 25 and 50 cc. of each agent.

To save repetition in the discussion of the results we shall refer to Cleveland Cliffs Iron Company's flotation oil No. 1 as oil No. 1, and to General Naval Stores' flotation oil No. 17 as oil No. 17. The reader should bear in mind that when statements are made that a certain reagent raised or lowered the grade of concentrate or extraction, those results are compared with the results obtained when oil was used without any reagent.

SULPHATES

Table I and Chart I show the results obtained with Cleveland Cliffs Iron Company's flotation oil No. 1 (hardwood creosote) Table II and Chart II show the results obtained with General Naval Stores flotation oil No. 17, and Table III and Chart III show the results obtained with cresylic acid.

TABLE I

Oil, Cleveland Cliff Iron Co.'s Flotation Oil No. 1.
Amount used, 0.5 pound per ton.
Addition Agents, 5% Solution by weight.

Operating Data.
Time, 40 to 45 minutes.
Speed of machine, 1700 r.p.m.

	Charge			Addition Agent		Concentrate		Tailings	Extraction
Test No.	Lead %	Ore Gms.	Dilution by wt.	Kind	Amt cc.	Wt. Gms.	Lead %	Lead %	%
1	4.30	800	1 to 5	None	None	47.0	68.6	0.22	94
2	4.30	800	1 to 5	"	"	51.0	62.8	0.27	94
3	4.90	800	1 to 5	"	"	58.0	62.7	0.25	93
0	....	...	......	Average Oil			64.7		93.3
4	4.30	800	1 to 5	H_2SO_4	5	45.0	65.0	0.62	85
5	4.30	800	1 to 5	"	15	43.0	68.2	0.61	85
6	4.64	700	1 to 5½	"	25	40.0	65.6	0.76	80
7	4.64	700	1 to 5½	"	50	42.0	62.8	0.67	84
8	4.64	624	1 to 6½	$BaSO_4$	5	36.0	66.6	0.72	83
9	4.64	624	1 to 6½	"	15	35.0	66.6	0.80	80
10	4.64	624	1 to 6½	"	25	35.0	67.2	0.75	81
11	4.64	624	1 to 6½	"	50	36.0	67.2	0.74	83
12	4.64	624	1 to 6½	$CaSO_4.2H_2O$	5	34.0	64.1	0.92	75
13	4.64	624	1 to 6½	"	15	38.0	62.1	0.82	80
14	4.64	624	1 to 6½	"	25	38.0	64.1	0.71	84
15	4.64	624	1 to 6½	"	50	34.0	60.2	1.21	71
16	4.64	700	1 to 5½	$MgSO_4.7H_2O$	5	40.0	65.5	0.69	81
17	4.64	700	1 to 5½	"	15	48.0	60.3	0.34	89
18	4.64	700	1 to 5½	"	25	40.0	68.7	0.48	87
19	4.64	700	1 to 5½	"	50	41.0	67.8	0.47	86
20	4.30	800	1 to 5	$Na_2SO_4.10H_2O$	5	38.0	63.6	1.22	70
21	4.30	800	1 to 5	"	15	45.0	60.8	0.87	80
22	4.30	800	1 to 5	"	25	40.0	60.2	1.27	70
23	4.30	800	1 to 5	"	50	53.0	57.2	0.51	88
24	4.64	700	1 to 5½	K_2SO_4	5	40.0	65.3	0.72	80
25	4.64	700	1 to 5½	"	15	40.0	65.9	0.71	80
26	4.64	700	1 to 5½	"	25	45.0	65.5	0.43	91
27	4.64	700	1 to 5½	"	50	42.0	66.6	0.63	83
28	4.30	800	1 to 5	$(NH_4)_2SO_4$	5	49.0	54.8	0.90	78
29	4.30	800	1 to 5	"	15	50.0	53.4	0.93	78
30	4.30	800	1 to 5	"	25	48.0	55.2	0.97	77
31	4.30	800	1 to 5	"	50	47.0	57.6	0.88	79
32	4.64	624	1 to 6½	$NaHSO_4.H_2O$	5	40.0	60.2	0.57	83
33	4.64	624	1 to 6½	"	15	38.0	68.7	0.39	90
34	4.64	624	1 to 6½	"	25	38.0	66.7	0.44	87
35	4.64	624	1 to 6½	"	50	40.0	62.7	0.46	86
36	4.64	648	1 to 6	$KHSO_4$	5	38.0	67.0	0.62	85
37	4.64	648	1 to 6	"	15	38.0	67.0	0.68	85
38	4.64	648	1 to 6	"	25	34.0	66.0	0.83	74
39	4.64	648	1 to 6	"	50	35.0	67.6	0.76	75

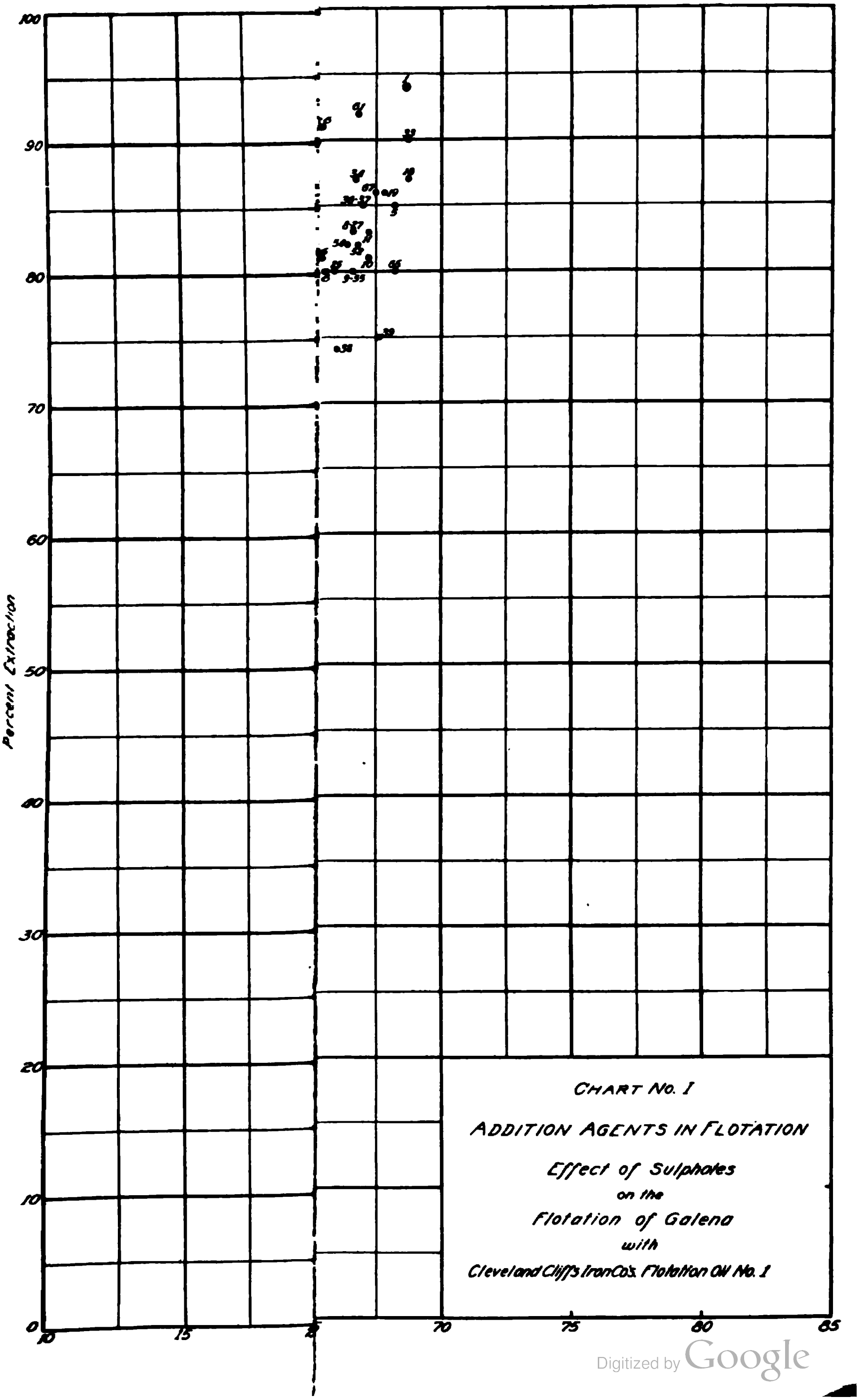


CHART No. I

ADDITION AGENTS IN FLOTATION

Effect of Sulphates
on the
Flotation of Galena
with
Cleveland Cliffs Iron Co's. Flotation Oil No. 1

TABLE I—(Cont.)

	Charge			Addition Agent		Concentrate		Tailings	Extraction
Test No.	Lead %	Ore Gms.	Dilution by wt.	Kind	Amt cc.	Wt. Gms.	Lead %	Lead %	%
40	4.30	800	1 to 5	$Fe(NH_4)(SO_4)_2.6H_2O$	5	42.0	61.6	1.10	75
41	4.30	800	1 to 5	"	15	44.0	60.8	0.96	78
42	4.30	800	1 to 5	"	25	44.0	61.2	1.00	78
43	4.30	800	1 to 5	"	50	43.0	63.8	0.90	80
44	4.30	800	1 to 5	$KAl(SO_4)_2.12H_2O$	5	45.0	62.4	0.78	81
45	4.30	800	1 to 5	"	15	41.0	61.2	1.18	73
46	4.30	800	1 to 5	"	25	43.0	61.2	1.08	76
47	4.30	800	1 to 5	"	50	40.0	62.2	1.21	72
48	4.64	576	1 to 7	$NH_4Al(SO_4)_2.12H_2O$	5	37.0	57.0	0.96	79
49	4.64	576	1 to 7	"	15	40.0	52.4	1.00	78
50	4.64	576	1 to 7	"	25	35.0	54.4	1.22	71
51	4.64	576	1 to 7	"	50	38.0	54.4	1.06	77
52	4.64	576	1 to 7	$NH_4Fe(SO_4)_2.12H_2O$	5	33.0	66.8	0.82	82
53	4.64	576	1 to 7	"	15	36.0	63.5	0.78	85
54	4.64	576	1 to 7	"	25	33.0	66.4	0.76	82
55	4.64	576	1 to 7	"	50	32.0	66.6	0.88	80
56	4.64	624	1 to 6½	$KCr(SO_4)_2.12H_2O$	5	35.0	64.9	0.88	79
57	4.64	624	1 to 6½	"	15	42.0	52.7	0.92	77
58	4.64	624	1 to 6½	"	25	36.0	62.3	0.97	77
59	4.64	624	1 to 6½	"	50	46.0	48.2	1.11	77
60	4.64	624	1 to 6½	$MnSO_4.4H_2O$	5	40.0	63.1	0.54	87
61	4.64	624	1 to 6½	"	15	40.0	66.8	0.32	92
62	4.64	624	1 to 6½	"	25	43.0	64.1	0.26	95
63	4.64	624	1 to 6½	"	50	50.0	60.6	0.48	88
64	4.64	680	1 to 6	$FeSO_4.7H_2O$	5	42.0	61.4	0.78	80
65	4.64	680	1 to 6	"	15	37.0	68.2	0.81	80
66	4.64	680	1 to 6	"	25	42.0	63.0	0.63	84
67	4.64	680	1 to 6	"	50	40.0	67.5	0.60	86
68	4.64	800	1 to 5	$HgSO_4$	5	43.0	61.2	1.18	71
69	4.64	800	1 to 5	"	15	48.0	59.2	1.03	77
70	4.64	800	1 to 5	"	25	45.0	60.8	1.12	74
71	4.64	800	1 to 5	"	50	54.0	58.8	0.61	86
72	4.30	800	1 to 5	$CuSO_4.5H_2O$	5	48.0	51.8	1.10	72
73	4.30	800	1 to 5	"	15	47.0	52.2	1.16	71
74	4.30	800	1 to 5	"	25	52.0	52.6	0.81	79
75	4.30	800	1 to 5	"	50	50.0	52.8	0.92	77
				TABLE I—(Cont.)					
76	4.55	800	1 to 5	$Zn(SO_4).7H_2O$	5	60.0	55.2	0.42	91
77	4.55	800	1 to 5	"	15	62.0	51.2	0.61	87
78	4.55	800	1 to 5	"	25	64.5	50.4	0.57	88
79	4.55	800	1 to 5	"	50	71.0	46.8	0.46	91
80	4.64	800	1 to 5	$Cd(SO_4).4H_2O$	5	16.0	38.0	3.76	16
81	4.64	800	1 to 5	"	15	13.0	30.1	4.07	11
82	4.64	800	1 to 5	"	25	13.0	30.6	4.03	11
83	4.64	800	1 to 5	"	50	14.0	32.4	3.96	12

TABLE II.

Oil, General Naval Stores Flotation Oil No. 17.
Amount used, 0.5 pound per ton.
Addition Agents, 5% Solution by weight.

Operating Data.
Time, 40 to 45 minutes.
Speed of machine, 1700 r.p.m.

	Charge			Addition Agent		Concentrate		Tailings	Extraction
Test No.	Lead %	Ore Gms.	Dilution by wt.	Kind	Amt cc.	Wt. Gms.	Lead %	Lead %	%
1	4.30	800	1 to 5	None	None	47.0	67.8	0.31	94
2	4.30	800	1 to 5	"	"	52.0	61.3	0.32	93
3	4.90	800	1 to 5	"	"	57.0	62.6	0.37	91
0	....	...	....	Average Oil	..	....	63.9	....	92.7
4	4.30	800	1 to 5	H_2SO_4	5	44.0	63.2	0.82	81
5	4.30	800	1 to 5	"	15	42.0	68.8	0.62	84
6	4.30	800	1 to 5	"	25	46.0	60.8	0.81	81
7	4.30	800	1 to 5	"	50	52.0	59.4	0.48	90
8	4.64	800	1 to 5	$BaSO_4$	5	50.0	63.6	0.70	85
9	4.64	800	1 to 5	"	15	48.0	64.3	0.72	83
10	4.64	800	1 to 5	"	25	47.0	65.8	0.80	80
11	4.64	800	1 to 5	"	50	45.0	66.2	0.82	80
12	4.64	800	1 to 5	$CaSO_4.2H_2O$	5	47.0	70.1	0.53	89
13	4.30	800	1 to 5	"	15	42.0	66.7	0.80	81
14	4.30	800	1 to 5	"	25	44.0	67.6	0.61	86
15	4.30	800	1 to 5	"	50	43.0	67.2	0.73	84
16	4.64	800	1 to 5	$MgSO_4.7H_2O$	5	46.0	64.2	0.94	80
17	4.64	800	1 to 5	"	15	51.0	61.4	0.73	85
18	4.64	800	1 to 5	"	25	49.0	67.0	0.53	88
19	4.30	800	1 to 5	"	50	45.0	66.5	0.52	87
20	4.64	800	1 to 5	$Na_2SO_4.10H_2O$	5	47.0	66.6	0.72	84
21	4.64	800	1 to 5	"	15	45.0	68.6	0.80	83
22	4.64	800	1 to 5	"	25	48.0	63.2	0.83	82
23	4.64	800	1 to 5	"	50	49.0	66.6	0.60	88
24	4.64	624	1 to 6½	K_2SO_4	5	48.0	54.4	0.27	90
25	4.64	624	1 to 6½	"	15	38.0	62.8	0.65	82
26	4.64	624	1 to 6½	"	25	42.0	58.2	0.54	84
27	4.64	624	1 to 6½	"	50	43.0	59.6	0.40	89
28	4.30	800	1 to 5	$(NH_4)_2SO_4$	5	53.0	61.6	0.20	95
29	4.30	800	1 to 5	"	15	52.0	60.2	0.37	91
30	4.30	800	1 to 5	"	25	50.0	60.8	0.51	88
31	4.30	800	1 to 5	"	50	50.0	59.2	0.62	87
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36	4.64	800	1 to 5	$KHSO_4$	5	47.0	66.2	0.53	85
37	4.64	800	1 to 5	"	15	47.0	65.8	0.68	83
38	4.64	800	1 to 5	"	25	44.0	68.0	0.97	80
39	4.64	800	1 to 5	"	50	45.0	66.6	0.94	81

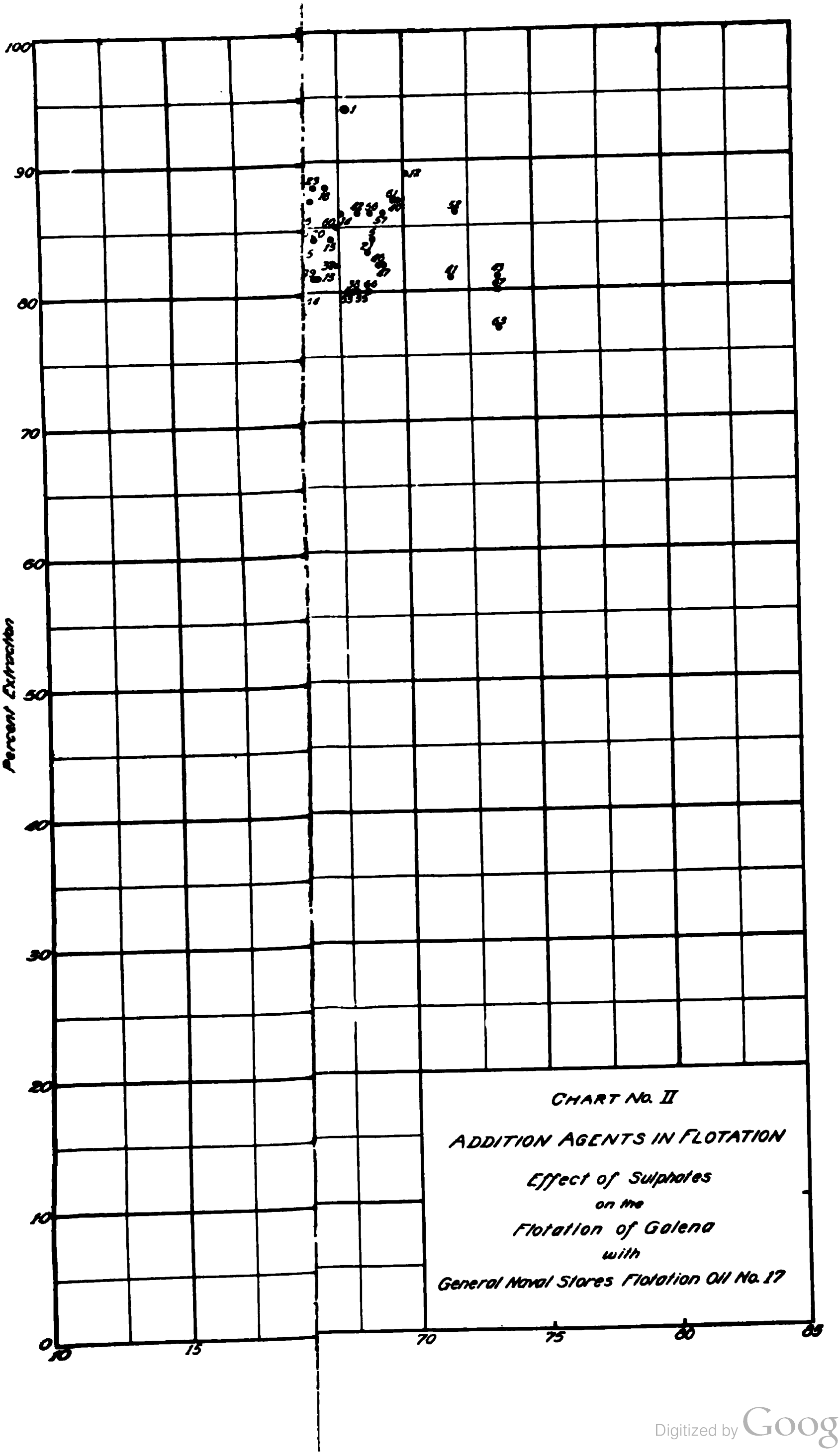

CHART No. II

ADDITION AGENTS IN FLOTATION

Effect of Sulphates
on the
Flotation of Galena
with
General Naval Stores Flotation Oil No. 17

TABLE II—(Cont.)

	Charge.			Addition Agent		Concentrate		Tailings	Extraction
Test No.	Lead %	Ore Gms.	Dilution by wt.	Kind	Amt cc.	Wt. Gms.	Lead %	Lead %	%
40	4.64	800	1 to 5	$Fe(NH_4)_2(SO)_2.6H_2O$	5	46.0	69.8	0.61	87
41	4.64	800	1 to 5	"	15	42.0	71.8	0.84	81
42	4.64	800	1 to 5	"	25	47.0	68.2	0.64	86
43	4.64	800	1 to 5	"	50	41.0	73.6	0.83	81
44	4.64	800	1 to 5	$KA1(SO_4)_2.12H_2O$	5	44.0	66.1	0.92	80
45	4.64	800	1 to 5	"	15	47.0	66.0	0.65	83
46	4.64	800	1 to 5	"	25	44.0	69.0	0.73	82
47	4.64	800	1 to 5	"	50	44.0	69.2	0.70	82
48	4.30	800	1 to 5	$NH_4A1(SO_4)_2.12H_2O$	5	50.0	59.8	0.57	87
49	4.30	800	1 to 5	"	15	49.0	59.2	0.63	84
50	4.30	800	1 to 5	"	25	50.0	59.8	0.51	87
51	4.30	800	1 to 5	"	50	49.0	59.6	0.60	85
52	4.64	800	1 to 5	$NH_4Fe(SO_4)_2.12H_2O$	5	45.0	72.0	0.62	86
53	4.30	800	1 to 5	"	15	41.0	67.8	0.97	80
54	4.30	800	1 to 5	"	25	43.0	65.6	0.80	82
55	4.30	800	1 to 5	"	50	40.0	68.2	0.92	80
56	4.30	800	1 to 5	$KCr(SO_4)_2.12H_2O$	5	43.0	68.7	0.60	86
57	4.30	800	1 to 5	"	15	43.0	69.2	0.61	86
58	4.30	800	1 to 5	"	25	50.0	60.4	0.52	88
59	4.30	800	1 to 5	"	50	48.0	60.2	0.70	84
60	4.64	800	1 to 5	$MnSO_4.4H_2O$	5	47.0	67.4	0.66	85
61	4.64	800	1 to 5	"	15	46.0	69.6	0.58	87
62	4.64	800	1 to 5	"	25	48.0	64.8	0.64	85
63	4.64	800	1 to 5	"	50	39.0	73.6	1.10	77
64	4.64	800	1 to 5	$FeSO_4 7H_2O$	5	50.0	63.6	0.61	86
65	4.64	800	1 to 5	"	15	50.0	64.8	0.55	87
66	4.30	800	1 to 5	"	25	40.0	68.6	0.90	80
67	4.30	800	1 to 5	"	50	37.0	73.6	0.92	80
68	4.30	800	1 to 5	$HgSO_4$	5	42.0	62.2	1.07	76
69	4.30	800	1 to 5	"	15	48.0	60.8	0.66	84
70	4.64	800	1 to 5	"	25	47.0	66.2	0.63	84
71	4.64	800	1 to 5	"	50	51.0	58.2	0.84	80
72	4.64	800	1 to 5	$CuSO_4.5H_2O$	5	55.0	51.6	1.12	76
73	4.64	800	1 to 5	"	15	57.0	50.0	1.08	77
74	4.64	800	1 to 5	"	25	62.0	51.6	0.70	86
75	4.64	800	1 to 5	"	50	59.0	51.8	0.81	82
76	4.55	800	1 to 5	$ZnSO_4.7H_2O$	5	57.0	56 4	0.50	88
77	4.55	800	1 to 5	"	15	61.5	54.4	0.37	92
78	4.55	800	1 to 5	"	25	61.5	52.2	0.46	88
79	4.55	800	1 to 5	"	50	71.0	49.8	0.24	97
80	4.64	800	1 to 5	$CdSO_4.4H_2O$	5	22.0	30.2	3.69	18
81	4.64	800	1 to 5	"	15	26.0	28.6	3.58	20
82	4.64	800	1 to 5	"	25	27.0	27.8	3.67	20
83	4.64	800	1 to 5	"	50	30.0	24.2	3.72	19

TABLE III

Oil, Cresylic Acid.
Amount used, 0.5 pound per ton.
Addition Agents, 5% Solution by weight.

Operating Data.
Time, 40 to 45 minutes.
Speed of machine, 1700 r.p.m.

	Charge			Addition Agent		Concentrate		Tailings	Extraction
Test No.	Lead %	Ore Gms.	Dilution by wt.	Kind	Amt cc.	Wt. Gms.	Lead %	Lead %	%
1	4.30	800	1 to 5	None	None	50.0	59.6	0.53	87
2	4.30	800	1 to 5	"	"	49.0	61.4	0.54	87
3	4.90	800	1 to 5	"	"	56.0	60.4	0.61	86
0	....	....	......	Average Oil	..	....	60.5	....	86.7
4	4.30	800	1 to 5	H_2SO_4	5	45.0	65.6	0.61	86
5	4.30	800	1 to 5	"	15	42.0	65.8	0.84	80
6	4.30	800	1 to 5	"	25	44.0	62.2	0.88	80
7	4.30	800	1 to 5	"	50	45.0	60.8	0.90	80
8	4.64	670	1 to 6	$BaSO_4$	5	47.0	62.8	0.27	95
9	4.64	670	1 to 6	"	15	49.0	59.8	0.22	94
10	4.64	670	1 to 6	"	25	48.0	60.2	0.23	93
11	4.64	670	1 to 6	"	50	50.0	60.3	0.19	97
12	4.64	670	1 to 6	$CaSO_4.2H_2O$	5	49.0	60.8	0.21	96
13	4.64	670	1 to 6	"	15	47.0	60.8	0.27	92
14	4.64	670	1 to 6	"	25	48.0	58.4	0.30	90
15	4.64	670	1 to 6	"	50	48.0	60.2	0.30	93
16	4.64	700	1 to 5½	$MgSO_4.7H_2O$	5	47.0	56.1	0.84	81
17	4.64	700	1 to 5½	"	15	45.0	54.9	1.18	76
18	4.64	700	1 to 5½	"	25	39.0	60.4	1.30	72
19	4.64	700	1 to 5½	"	50	37.0	65.3	1.21	74
20	4.64	670	1 to 6	$Na_2SO_4.10H_2O$	5	50.0	60.2	0.22	96
21	4.64	670	1 to 6	"	15	49.0	60.2	0.21	95
22	4.64	670	1 to 6	"	25	50.0	60.0	0.24	96
23	4.64	670	1 to 6	"	50	50.0	60.0	0.22	96
24	4.30	800	1 to 5	K_2SO_4	5	49.0	56.6	0.87	81
25	4.64	624	1 to 6½	"	15	46.0	50.7	0.90	80
26	4.64	624	1 to 6½	"	25	46.0	51.5	0.78	82
27	4.64	624	1 to 6½	"	50	46.0	50.7	0.93	80
28	4.30	800	1 to 5	$(NH_4)_2SO_4$	5	48.0	61.8	0.62	86
29	4.30	800	1 to 5	"	15	51.0	61.2	0.41	90
30	4.30	800	1 to 5	"	25	50.0	60.0	0.56	87
31	4.30	800	1 to 5	"	50	50.0	62.6	0.40	91
32	4.64	800	1 to 5	$NaHSO_4.H_2O$	5	47.0	65.2	0.81	83
33	4.64	800	1 to 5	"	15	54.0	61.6	0.48	90
34	4.64	800	1 to 5	"	25	49.0	63.2	0.80	83
35	4.30	800	1 to 5	"	50	48.0	62.9	0.51	88
36	4.64	670	1 to 6	$KHSO_4$	5	48.0	60.8	0.30	93
37	4.64	800	1 to 5	"	15	49.0	65.6	0.52	87
38	4.64	800	1 to 5	"	25	55.0	61.6	0.38	91
39	4.64	800	1 to 5	"	50	50.0	64.8	0.60	87

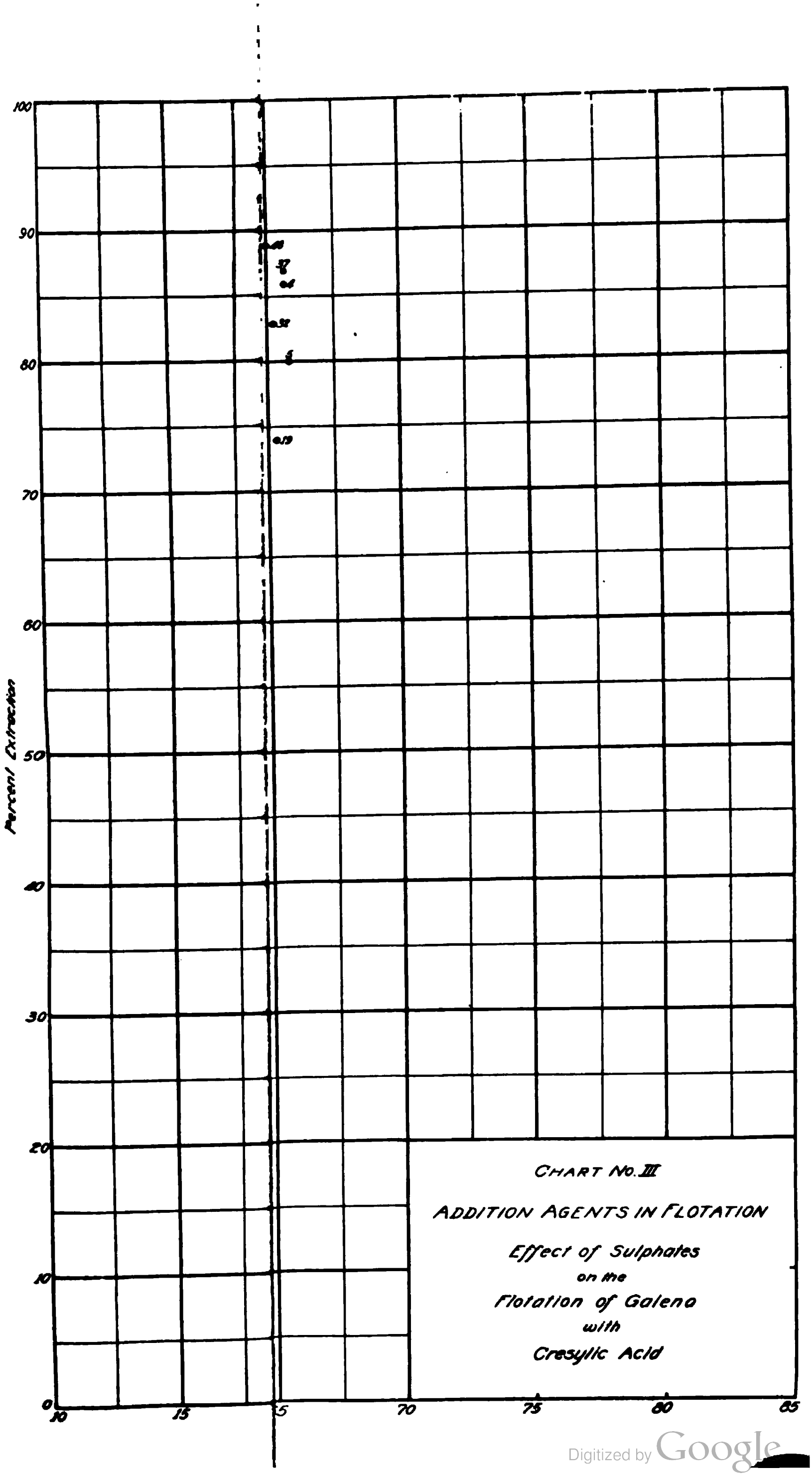

CHART NO. III

ADDITION AGENTS IN FLOTATION

Effect of Sulphates
on the
Flotation of Galena
with
Cresylic Acid

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TABLE III—(Cont.)

	Charge			Addition Agent		Concentrate		Tailings	Extraction
Test No.	Lead %	Ore Gms.	Dilution by wt.	Kind	Amt cc.	Wt. Gms.	Lead %	Lead %	%
40	4.30	800	1 to 5	$Fe(NH_4)_2(SO_4)_2.6H_2O$	5	53.0	61.6	0.21	95
41	4.30	800	1 to 5	"	15	52.0	62.2	0.26	94
42	4.30	800	1 to 5	"	25	50.0	62.4	0.38	91
43	4.30	800	1 to 5	"	50	50.0	62.4	0.41	91
44	4.30	800	1 to 5	$KAl(SO_4)_2.12H_2O$	5	40.0	62.2	1.21	72
45	4.64	672	1 to 6	"	15	44.0	61.4	0.62	86
46	4.64	672	1 to 6	"	25	44.0	62.2	0.60	87
47	4.30	800	1 to 5	"	50	40.0	60.2	1.30	70
48	4.30	800	1 to 5	$NH_4Al(SO_4)_2.12H_2O$	5	47.0	65.0	0.52	89
49	4.30	800	1 to 5	"	15	49.0	60.6	0.50	89
50	4.30	800	1 to 5	"	25	48.0	64.4	0.43	92
51	4.30	800	1 to 5	"	50	48.0	64.6	0.41	92
52	4.64	624	1 to 6½	$NH_4Fe(SO_4)_2.12H_2O$	5	42.0	60.6	0.51	88
53	4.64	624	1 to 6½	"	15	41.0	60.4	0.62	86
54	4.64	672	1 to 6	"	25	43.0	62.2	0.63	86
55	4.64	672	1 to 6	"	50	42.0	64.6	0.54	87
56	4.64	624	1 to 6½	$KCr(SO_4)_2.12H_2O$	5	43.0	56.3	0.81	83
57	4.64	624	1 to 6½	"	15	36.0	58.5	1.10	73
58	4.64	624	1 to 6½	"	25	41.0	50.1	1.18	71
59	4.64	624	1 to 6½	"	50	34.0	58.9	1.21	70
60	4.30	800	1 to 5	$MnSO_4.4H_2O$	5	46.0	62.2	0.74	83
61	4.30	800	1 to 5	"	15	45.0	62.4	0.80	82
62	4.30	800	1 to 5	"	25	46.0	61.8	0.76	82
63	4.30	800	1 to 5	"	50	45.0	62.4	0.81	82
64	4.64	700	1 to 5½	$FeSO_4.7H_2O$	5	49.0	54.4	0.84	82
65	4.64	700	1 to 5½	"	15	50.0	55.6	0.68	86
66	4.64	700	1 to 5½	"	25	50.0	52.3	0.94	81
67	4.64	700	1 to 5½	"	50	48.0	53.6	1.02	79
68	4.30	800	1 to 5	$HgSO_4$	5	47.0	61.8	0.70	84
69	4.30	800	1 to 5	"	15	47.0	58.6	0.86	80
70	4.30	800	1 to 5	"	25	45.0	58.2	1.06	76
71	4.30	800	1 to 5	"	50	47.0	54.4	1.12	75
72	4.64	800	1 to 5	$CuSO_4.5H_2O$	5	47.0	60.0	1.09	76
73	4.64	800	1 to 5	"	15	48.0	63.6	0.83	82
74	4.30	800	1 to 5	"	25	53.0	58.0	0.50	89
75	4.64	800	1 to 5	"	50	57.0	57.6	0.55	88
76	4.55	800	1 to 5	$ZnSO_4.7H_2O$	5	63.0	51.6	0.48	89
77	4.55	800	1 to 5	"	15	65.5	53.2	0.26	95
78	4.55	800	1 to 5	"	25	62.5	49.2	0.70	84
79	4.55	800	1 to 5	"	50	65.0	50.2	0.41	90
80	4.64	800	1 to 5	$CdSO_4.4H_2O$	5	27.0	38.2	3.29	28
81	4.64	800	1 to 5	"	15	22.0	34.4	3.62	24
82	4.64	800	1 to 5	"	25	22.0	33.2	3.68	20
83	4.64	800	1 to 5	"	50	19.0	31.8	3.87	16

Discussion of Results

In the discussion of the results shown in the tables and charts, the effect of each sulphate with the three oils will be considered separately, after which they will be thrown into groups and considered in a general manner.

Sulphuric Acid and Alkali-Earth Sulphates

H_2SO_4. Nos. 4 to 7. When sulphuric acid is added, the extraction is lowered without any apparent change in the grade of concentrate produced. This indicates that southeast Missouri lead ores will give better results without acid than with it.

$BaSO_4$. Nos. 8 to 11. Barium sulphate gives rather erratic results. With oils which produce a clean concentrate with a good extraction, the presence of this reagent lowers the extraction without any great change in the grade of concentrate produced; but with an oil which tends to lift the gangue, its presence seems to improve the extraction.

$CaSO_4.2H_2O$. Nos. 12 to 15. Calcium sulphate has practically the same effect as barium sulphate.

$MgSO_4.7H_2O$. Nos. 16 to 19. The addition of magnesium sulphate lowers the extraction without any great change in the grade of concentrate produced.

Summary. The action of sulphuric acid, which with this ore forms calcium and magnesium sulphates, and the action of the individual sulphates of the alkali-earths, are very similar. With the exception of barium and calcium sulphates, when used with cresylic acid, the extraction is lowered about 10 per cent and there is very little difference in the grade of concentrate produced.

Alkali Sulphates

$Na_2SO_4.10H_2O$. Nos. 20 to 23. The presence of sodium sulphate seems to have little effect on the grade of concentrate produced, but it does have a noticeable effect on the extraction obtained. The extraction may be better or poorer, depending upon the quantity of sodium sulphate used and on the oil used.

K_2SO_4. Nos. 24 to 27. When potassium sulphate is added, both the extraction and the grade of concentrate are to some extent lowered.

$(NH_4)_2SO_4$. Nos. 28 to 31. The results obtained with ammonium sulphate show that they depend more on the oil used than on the qanutity of the salt present in solution. The results do not deviate sufficiently to make experimental work promising.

$NaHSO_4.H_2O$. Nos. 32 to 35. The results obtained when using sodium acid sulphate are somewhat erratic. As there are no great variations either in the grade of concentrate or in the extraction, no attempt was made to determine if there were critical quantities which would produce a marked result.

$KHSO_4$. Nos. 36 to 39. The tendency of potassium acid sulphate is to give a concentrate of slightly higher grade while it decreases the extraction.

Summary. The acid and normal suplhates of the alkalies do not show sufficient deviation from each other, either from the results obtained when using oil alone, or from the results of one when compared with the results of another, to make further experimental work desirable at this time.

Alums

$Fe(NH_4)_2SO_4)_2.6H_2O$. Nos. 40 to 43. The concentrate obtained when ferrous ammonium sulphate was added was of a little better grade than that produced with oil alone. The extraction varied with the oil used.

$KAl(SO_4)_2.12H_2O$. Nos. 44 to 47. When potassium alum was used there was a tendency to improve the grade of concentrate. It lowers the extraction to such an extent, however, that the improvement in the grade of concentrate is of no interest.

$NH_4Al(SO_4)_2.12H_2O$. Nos. 48 to 51. The effect of ammonium alum, when the results are considered as a whole, is to lower both the grade of the concentrate and the extraction.

$NH_4Fe(SO_4)_2.12H_2O$. Nos. 52 to 55. When ammonioferric alum was added, the extractions were lowered considerably with the oils which give a high extraction when no reagent was present. With cresylic acid there is practically no change in the extraction. The grade of concentrate is improved, varying slightly with the oil used.

$KCr(SO_4)_2.12H_2O$. Nos. 56 to 59. When the percentage of lead in the concentrate is considered, chrome alum does not have much effect. The results are rather erratic, but the extraction is uniformly lowered by the use of this salt.

Summary. When considering the alums and ferrous ammonium sulphate as a whole, the action of all these salts is very similar to those that have been discussed; for that reason no further discussion will be attempted.

Metallic Sulphates

$MnSO.4H_2O$. Nos. 60 to 63. Manganese sulphate, when present in solution, has little effect on the grade of concentrate produced. It does lower the extraction slightly.

$FeSO_4.7H_2O$. Nos. 64 to 67. The presence of ferrous sulphate causes variable results. With the oils which give a clean concentrate and high extraction it lowers the extraction, but has little effect on the grade of concentrate produced. With cresylic acid the lead tenor of the concentrate produced is noticeably lower.

$HgSO_4$. Nos. 68 to 71. The effect of mercuric sulphate is to lower the extraction without any very great change in the lead content of the concentrate.

$CuSO_4.5H_2O$. Nos. 72 to 75. Copper sulphate lowered the extraction very noticeably and also lowered the lead content of the concentrate. This is just the opposite of the results found in many cases when floating zinc ores.

$ZnSO_4.7H_2O$. Nos. 76 to 79. Zinc sulphate gives variable results. When considering the extraction it will be noted that some of them are a little higher and some slightly lower than when oil alone is used. Taken as a whole, the effect on the extraction is negligible, though it does cause a noticeable lowering of the lead content of the concentrate. When zinc sulphate is present, one might be justified in giving the pulp a preliminary water-wash in order to raise the grade of the concentrate, and thereby save freight and smelting charges.

$CdSO_4.8H_2O$. Nos. 80 to 83. The presence of cadmium sulphate is very detrimental, practically ruining both the extraction and the grade of concentrate obtained.

Summary of Effect of Sulphates

Generally, when the sulphates are present, the tendency is to lower both the grade of concentrate produced and the extraction. There are, however, a few exceptions to this rule. For instance, when using sodium sulphate with cresylic acid, about the same grade of concentrate is produced, but the extraction is noticeably higher. While a few instances may occur in which a certain salt has a slight beneficial effect, this effect is not nearly so pronounced as the detrimental effect of cadmium sulphate. In fact, the position of cadmium is quite unique among the other salts and for this reason it is our intention to publish later a study of the behavior of cadmium salts generally; hence no further discussion of this striking singularity will be attempted here.

The poor extraction obtained when sulphates are present can be overcome in some cases by giving the pulp a longer treatment. This, however, lowers the capacity of a given machine and increases the cost of treatment.

HYDROXIDES

Table IV and Chart IV show the results obtained with Cleveland Cliffs Iron Company's flotation oil No. 1. Table V and Chart V show the results obtained with General Naval Stores' flotation oil No. 17. Table VI and Chart VI show the results obtained with cresylic acid.

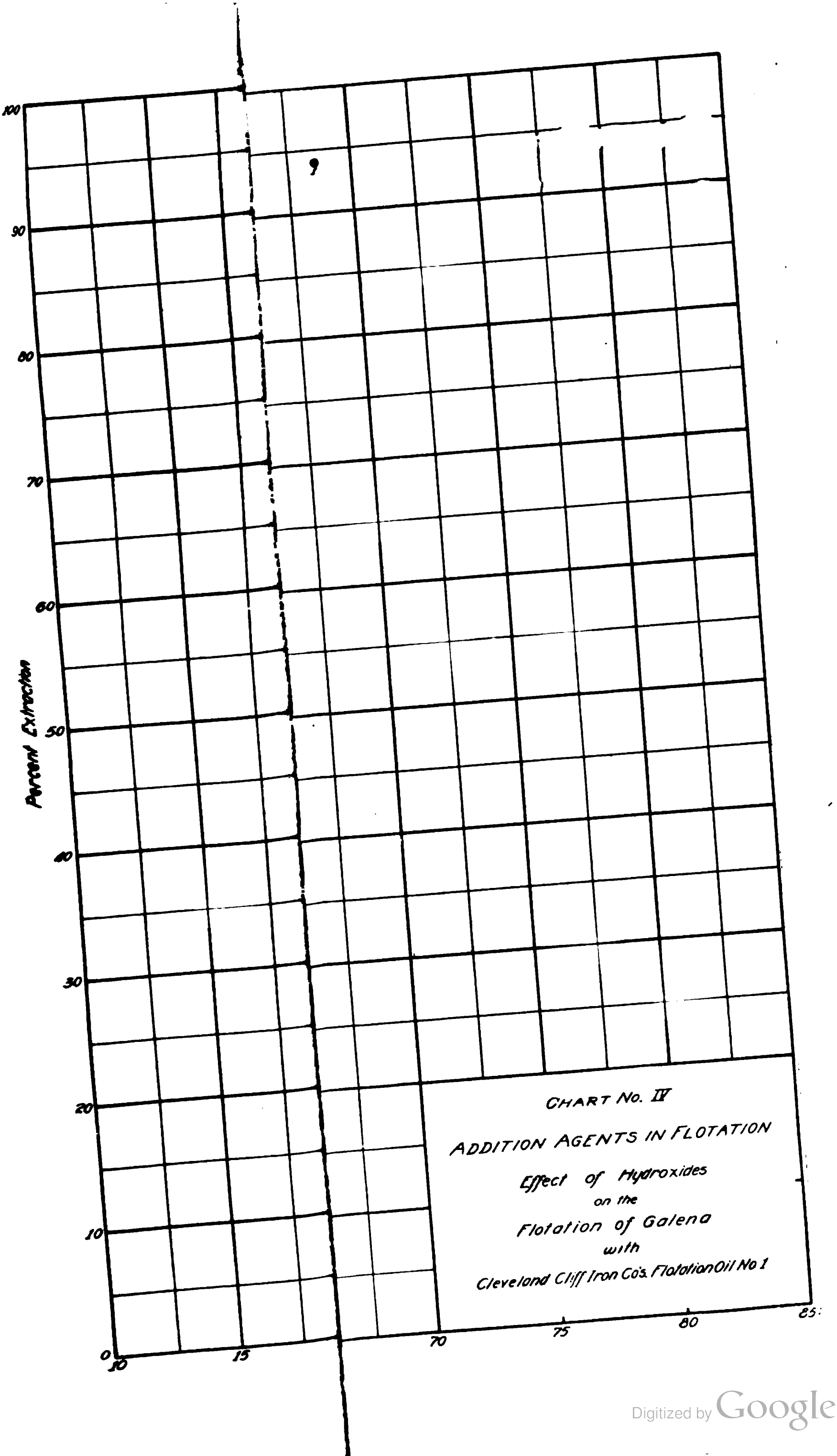
Percent Extraction
0
10
20
30
40
50
60
70
80
90
100
10
15
70
75
80
85
CHART No. IV
ADDITION AGENTS IN FLOTATION
Effect of Hydroxides
on the
Flotation of Galena
with
Cleveland Cliff Iron Co's Flotation Oil No 1

TABLE IV

Oil, Cleveland Cliff Iron Co.'s Flotation Oil No. 1. Operating Data.
Amount used, 0.5 pound per ton. Time, 40 to 45 minutes.
Addition Agents, 5% Solution by Weight. Amount of water, 4000cc.
Dilution, 1 to 5. Amount of ore, 800 grams.
Speed of machine, 1700 r.p.m.

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
1	4.30	None	None	47.0	68.6	0.22	94
2	4.30	"	"	51.0	62.8	0.27	93
3	4.90	"	"	58.0	62.7	0.25	93
0	....	Average Oil	....	....	64.7	....	93.3
4	4.30	NH_4OH	5	52.0	52.0	0.93	79
5	4.30	"	15	52.0	53.2	0.80	80
6	4.30	"	25	50.0	54.6	0.90	79
7	4.30	"	50	53.0	54.2	0.70	83
8	4.30	$Ba(OH)_2.8H_2O$	5	50.0	56.4	0.76	82
9	4.30	"	15	50.0	52.2	1.03	76
10	4.30	"	25	50.0	53.8	0.96	78
11	4.30	"	50	51.0	54.0	0.81	80
12	4.90	$Ca(OH)_2$	5	58.0	57.6	0.67	85
13	4.90	"	15	59.0	61.6	0.38	93
14	4.90	"	25	65.0	55.2	0.42	92
15	4.90	"	50	89.0	42.2	0.20	95
16	4.90	$Mg(OH)_2$	5	52.0	62.2	0.84	83
17	4.90	"	15	53.5	63.6	0.71	86
18	4.90	"	25	52.0	63.6	0.80	84
19	4.90	"	50	53.0	61.8	0.81	83
20	4.30	$NaOH$	5	52.0	53.4	0.80	81
21	4.30	"	15	48.0	58.0	0.83	80
22	4.30	"	25	55.0	50.2	0.80	80
23	4.30	"	50	54.0	52.2	0.78	82
24	4.30	KOH	5	55.0	58.0	0.32	93
25	4.30	"	15	54.0	59.2	0.30	93
26	4.30	"	25	48.0	62.2	0.63	87
27	4.30	"	50	50.0	59.0	0.67	86

TABLE V

Oil, General Naval Stores Flotation Oil No. 17. Operating Data.
Amount used, 0.5 pound per ton. Time, 40 to 45 minutes.
Addition Agents, 5% Solution by Weight. Amount of water, 4000cc.
Dilution, 1 to 5. Amount of ore, 800 grams.
Speed of machine, 1700 r.p.m.

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
1	4.30	None	None	47.0	67.8	0.31	94
2	4.30	"	"	52.0	61.3	0.32	93
3	4.90	"	"	57.0	62.6	0.37	91
0	....	Average Oil	..	....	63.9	....	92.7
4	4.30	NH_4OH	5	48.0	62.8	0.56	88
5	4.30	"	15	48.0	59.0	0.81	82
6	4.30	"	25	49.0	60.2	0.61	86
7	4.64	"	50	48.0	66.4	0.63	86
8	4.30	$Ba(OH)_2.8H_2O$	5	48.0	57.6	0.81	80
9	4.30	"	15	47.0	59.6	0.77	81
10	4.30	"	25	53.0	59.2	0.48	88
11	4.30	"	50	49.0	63.2	0.38	93
12	4.90	$Ca(OH)_2$	5	53.0	61.0	0.80	82
13	4.90	"	15	62.0	52.0	0.82	82
14	4.90	"	25	76.0	45.8	0.52	89
15	4.90	"	50	77.0	42.8	0.60	84
16	4.90	$Mg(OH)_2$	5	46.0	66.2	1.12	78
17	4.90	"	15	49.0	63.6	0.98	80
18	4.90	"	25	48.0	62.2	1.21	76
19	4.90	"	50	51.0	62.6	0.86	83
20	4.30	NaOH	5	48.0	64.2	0.43	90
21	4.30	"	15	49.0	59.6	0.76	85
22	4.30	"	25	49.0	62.0	0.50	88
23	4.30	"	50	54.0	57.2	0.41	90
24	4.30	KOH	5	55.0	57.2	0.40	91
25	4.30	"	15	54.0	58.8	0.33	92
26	4.30	"	25	53.0	56.2	0.60	86
27	4.30	"	50	54.0	54.2	0.69	85

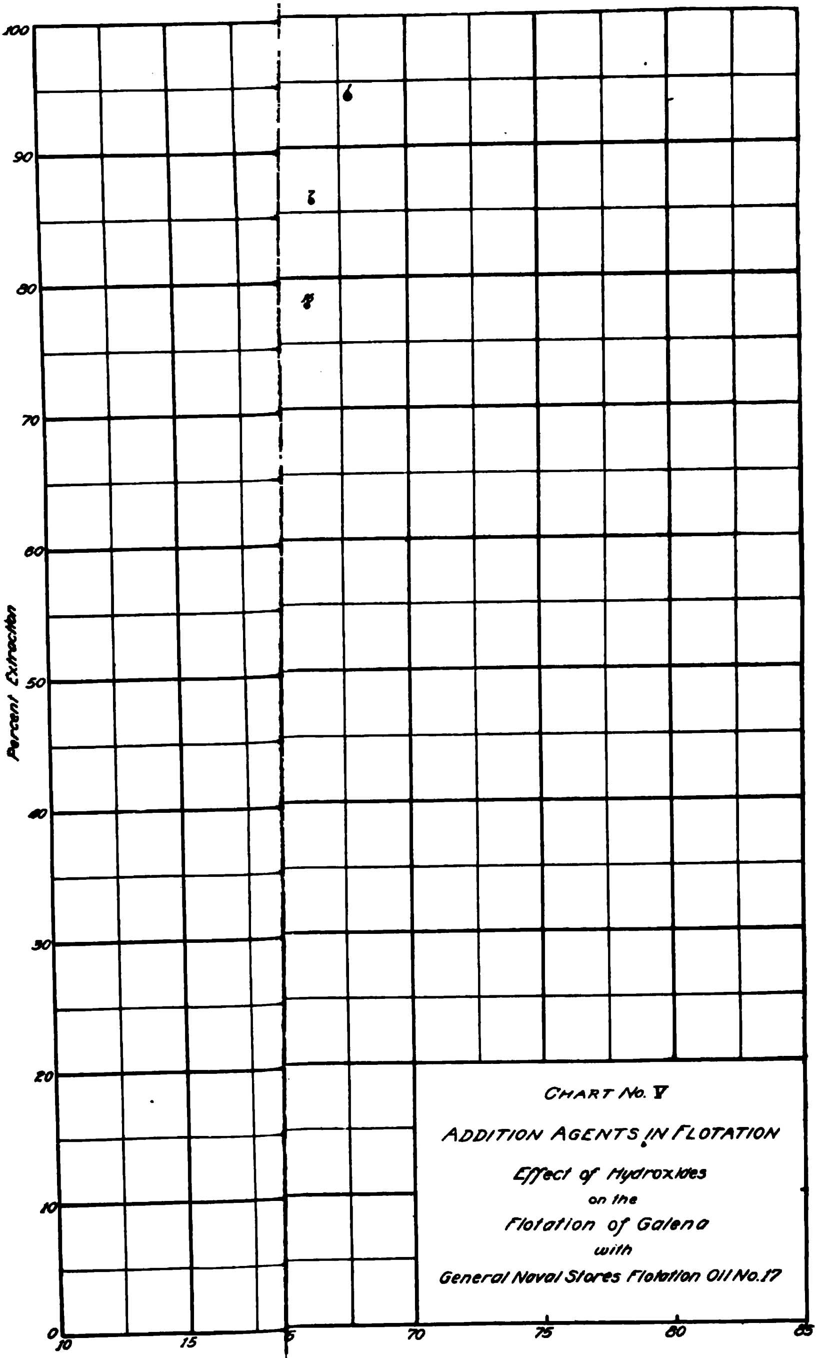

CHART No. V

ADDITION AGENTS IN FLOTATION

Effect of Hydroxides

on the

Flotation of Galena

with

General Naval Stores Flotation Oil No. 17

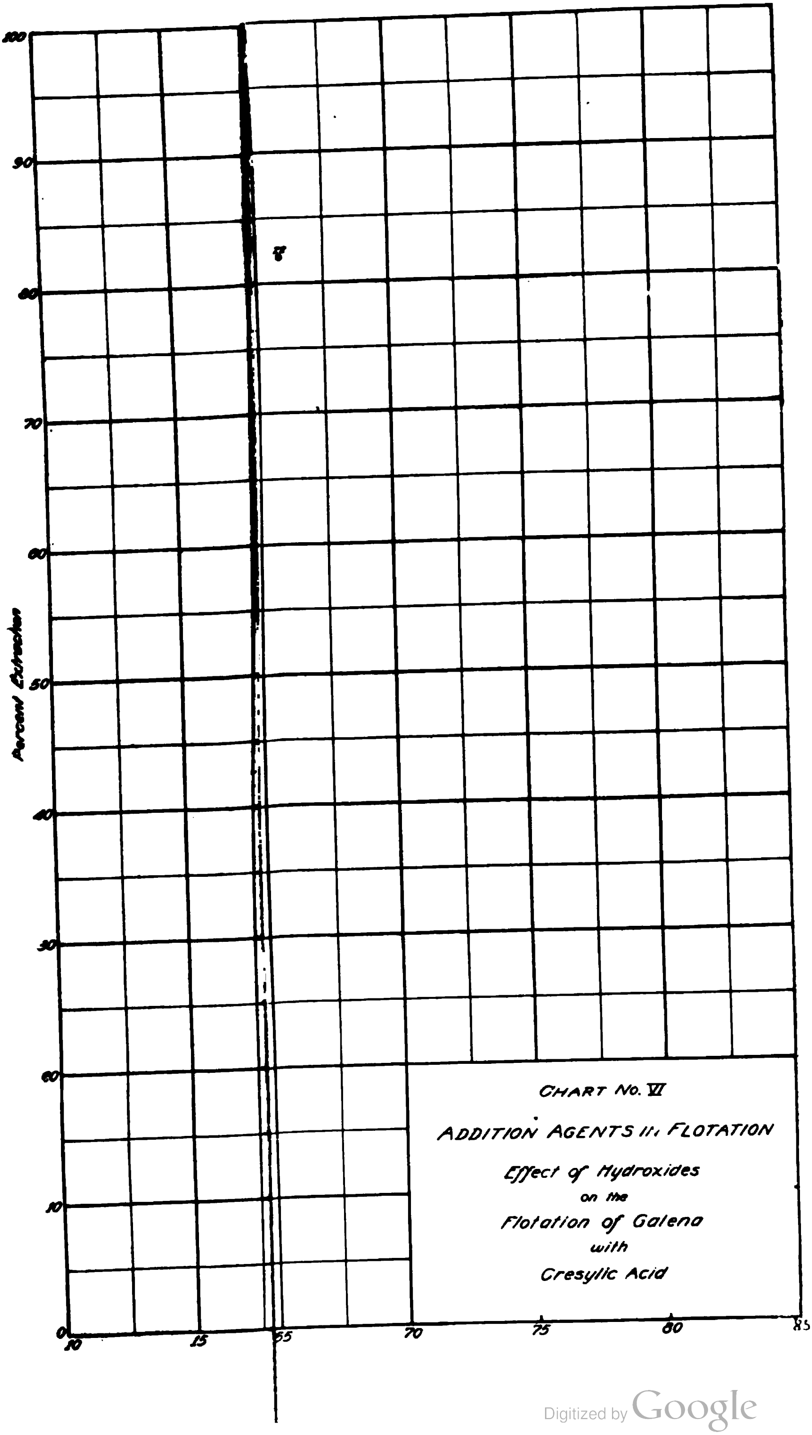

CHART No. VI

ADDITION AGENTS in FLOTATION

Effect of Hydroxides
on the
Flotation of Galena
with
Cresylic Acid

TABLE VI

Oil, Cresylic Acid.
Amount used, 0.5 pound per ton.
Addition Agent, 5% Solution by Weight.
Dilution, 1 to 5.

Operating Data.
Time, 40 to 45 minutes.
Amount of water, 4000cc.
Amount of ore, 800 grams.
Speed of machine, 1700 r.p.m.

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
1	4.30	None	None	50.0	59.6	0.53	87
2	4.30	"	"	49.0	61.4	0.54	87
3	4.90	"	"	56.0	60.4	0.61	86
0	....	Average Oil	..	....	60.5	....	86.7
4	4.30	NH_4OH	5	50.0	54.4	0.86	80
5	4.30	"	15	47.0	58.2	0.90	80
6	4.30	"	25	47.0	59.0	0.88	80
7	4.30	"	50	45.0	57.8	1.10	76
8	4.30	$Ba(OH)_2.8H_2O$	5	44.0	62.8	0.87	80
9	4.30	"	15	44.0	59.8	1.08	76
10	4.30	"	25	41.0	62.6	1.12	75
11	4.30	"	50	45.0	61.6	0.86	80
12	4.90	$Ca(OH)_2$	5	51.5	59.4	1.12	78
13	4.90	"	15	60.0	57.6	0.51	88
14	4.90	"	25	66.0	53.6	0.46	90
15	4.90	"	50	61.5	55.4	0.54	87
16	4.90	$Mg(OH)_2$	5	46.0	63.2	1.31	74
17	4.90	"	15	50.0	62.8	1.02	80
18	4.90	"	25	48.5	64.2	1.05	80
19	4.90	"	50	47.0	62.6	1.22	75
20	4.64	NaOH	5	47.0	61.6	1.08	79
21	4.30	"	15	43.0	63.0	1.04	79
22	4.30	"	25	43.0	65.8	0.81	82
23	4.30	"	50	45.0	57.2	1.27	75
24	4.30	KOH	5	45.0	63.6	0.76	83
25	4.30	"	15	44.0	63.1	0.83	81
26	4.30	"	25	44.0	62.8	0.85	80
27	4.30	"	50	45.0	62.2	0.82	81

$(NH_4)OH$. Nos. 4 to 7. Ammonium hydroxides, when used with both oil No. 17 and cresylic acid, produced very similar results. The relative extraction was lowered about 7 per cent, while the grade of concentrate produced was only about 3 per cent low. With oil No. 1 both the extraction and grade of concentrate were lowered about 12 per cent.

$Br(OH)_2.8H_2O$. Nos. 8 to 11. With oil No. 1, barium hydoxide lowered the extraction about 15 per cent, and also lowered the grade of concentrate about 10 per cent. With oil No. 17 the extraction was lowered 7 per cent, while the grade of concentrate was lowered 4 per cent. With cresylic acid the extraction and grade of concentrate were lowered 9 per cent.

$Ca(OH)_2$. Nos. 12 to 15. Calcium hydroxide, when used with oil No. 1, gave extractions which varied from 2 per cent high to 5 per cent low, while the lead tenor of the concentrate varied from 2 per cent low to 22 per cent low. With oil No. 17 the extraction varied from 4 per cent low to 10 per cent low. and the grade of concentrate varied from 2 per cent to 22 per cent low. With cresylic acid the extraction varied from 3 per cent high to about 8 per cent low, and the grade of concentrate varied from 2 per cent high to 6 per cent low.

Calcium hydroxide is practically the only hydroxide which exerted a pronounced effect on the character of the froth formed. With oil No. 1, 5 cc. of this salt gave a very wet froth composed of very small bubbles which formed slowly and broke down very quickly. With 15 cc. the froth was wet, and was composed of small bubbles which broke down slowly. With 25 cc. the froth was dry, and was composed of extremely large bubbles. This froth formed quickly, seemed to carry large quantities of gangue, and broke with difficulty. The froths with oil No. 17 were similar to those formed when oil No. 1 was used. With cresylic acid, 5 cc. of calcium hydroxide gave a wet froth composed of small bubbles which broke very quickly. The froth with 15 cc. was dry. When 25 cc. was used, no froth was obtained when the usual quantity of oil—0.5 lb. per ton—was added. To complete the experiment, another portion of oil equivalent to 0.250 lb. per ton was added. This extra addition of oil produced a froth composed of large bubbles which broke very quickly. With 50 cc. of this salt it was necessary to double the amount of oil before the tests could be completed. The froth formed when 1 lb. per ton of oil was added was extremely dry and was composed of very large bubbles.

The relation between the flocculating effect of this salt and its effect on flotation deserves more work than we can devote to it at the present time.

$Mg(OH)_2$. Nos. 16 to 19. Magnesium hydroxide, when used with any one of the three oils, lowered the extraction about 10 per cent and had very little effect on the grades of concentrates produced. This salt modified the froths formed to such a little extent that no further discussion is necessary.

NaOH. Nos. 20 to 23. When sodium hydroxide was used, the results were so nearly like those of ammonium hydroxide that further discussion is unnecessary.

KOH. Nos. 24 to 27. Potassium hydroxide, when used with oils No. 1 and No. 17, lowered the extraction about 4 per cent, while the grade of concentrate produced was lowered about 6 per cent. Observations and results indicate that there is a possible relation between the flocculating effect of this salt and its effect on flotation results. However, it will take many more determinations to demonstrate the correctness or fallacy of this apparent relation. When this salt was used with cresylic acid the results checked more closely. The average extractions were lowered about 5 per cent, while the average grade of the concentrates was raised 2 per cent.

Summary of Effect of Hydroxides

The limited number of hydroxides tested, when considered as a group, produce results which are very similar to the results obtained when sulphates are present. The relative extraction is practically the same, but the grade of concentrates produced is slightly lower than when sulphates are present.

NITRATES

The results of these experiments are set forth in Tables VII. VIII and IX and in Charts VII, VIII and IX.

Nitric acid and many of the commoner nitrates, when used in flotation, tend to produce such an abundance of froth that it was found impractical to add the total amount of oil—0.5 lb. per ton—at the beginning of the test. When the total amount of oil was added at one time, the entire amount of froth produced was evolved so quickly that an excessive overflow carrying large quantities of gangue was obtained, thereby necessitating the discarding of the test. To overcome this difficulty, the method of handling the nitrates was modified in the following manner: The desired quantity of the reagent having been added to the charge oil was added at intervals in quantities equivalent to 0.125 lb. per ton. After each addition of oil the violent frothing was allowed to subside before another portion of oil was added. This procedure was continued until the total amount of oil—0.5 lb. per ton—had been added, and the test was then completed, as described in the method for sulphates.

This tendency of quickly producing a very copious froth was so pronounced with nitric acid that it was found impossible to complete an experiment in which acid had been used, and so after twelve or fifteen trials its use was abandoned.

The character and quantity of froth obtained when the nitrates were used varied widely. Small quantities of one reagent produced a froth composed of large bubbles, while larger quantities of the same reagent produced a froth of small bubbles. This condition was reversed with some of the other reagents. Repeated tests, however, with the same addition agent under uniform operating conditions maintained in this work always gave a froth having the same characteristics as mentioned above.

Many of the tests were completed in from 25 to 30 minutes, but were continued the full 40 minutes in order to keep operating conditions as uniform as possible.

TABLE VII

Oil, Cleveland Cliff Iron Co.'s Flotation Oil No. 1.
[illegible] Amount used, 0.5 pound per ton.
Addition Agents, 5% Solution by Weight.
Dilution, 1 to 5.

Operating Data.
Time, 40 to 45 minutes.
Amount of water, 4000cc.
Amount of ore, 800 grams.
Speed of machine, 1700 r.p.m.

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
1	4.30	None	None	47.0	68.6	0.22	94
2	4.30	"	"	51.0	62.8	0.27	93
3	4.90	"	"	58.0	62.7	0.25	93
0	....	Average Oil	..	....	64.7	....	93.3
4	4.55	$Ba(NO_3)_2$	5	81.5	42.2	0.28	94
5	4.55	"	15	71.5	46.6	0.34	91
6	4.55	"	25	71.5	45.0	0.50	89
7	4.55	"	50	65.0	47.6	0.73	85
8	4.55	$Ca(NO_3)_2.4H_2O$	5	67.5	50.2	0.30	93
9	4.55	"	15	67.0	51.0	0.26	93
10	4.55	"	25	65.5	50.1	0.54	90
11	4.55	"	50	63.5	49.8	0.62	87
12	4.55	$Sr(NO_3)_2.4H_2O$	5	76.5	46.0	0.21	96
13	4.55	"	15	74.5	45.6	0.34	93
14	4.55	"	25	71.0	49.0	0.20	95
15	4.55	"	50	72.5	48.0	0.22	95
16	4.55	$Mg(NO_3)_2.7H_2O$	5	73.5	46.0	0.32	93
17	4.55	"	15	69.0	48.4	0.36	92
18	4.55	"	25	74.0	44.8	0.41	91
19	4.55	"	50	72.0	45.6	0.43	90
20	4.55	$NaNO_3$	5	72.5	46.8	0.32	93
21	4.55	"	15	70.5	48.2	0.30	93
22	4.55	"	25	69.0	48.6	0.40	92
23	4.55	"	50	72.0	48.0	0.22	94
24	4.55	KNO_3	5	67.5	47.4	0.50	88
25	4.55	"	15	71.5	46.8	0.35	91
26	4.55	"	25	66.0	47.8	0.60	87
27	4.55	"	50	69.5	46.0	0.48	88
28	4.55	NH_4NO_3	5	64.5	53.8	0.23	95
29	4.55	"	15	61.0	51.6	0.58	87
30	4.55	"	25	66.5	49.6	0.42	91
31	4.55	"	50	65.0	49.8	0.49	89

TABLE VII—(Cont.)

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
32	4.55	$LiNO_3$	5	73.0	46.4	0.32	93
33	4.55	"	15	72.5	47.4	0.31	94
34	4.55	"	25	71.5	47.2	0.30	93
35	4.55	"	50	73.5	45.6	0.40	92
36	4.55	$Mn(NO_3)_2.6H_2O$	5	70.5	47.2	0.40	91
37	4.55	"	15	73.5	46.4	0.33	93
38	4.55	"	25	70.0	48.8	0.27	93
39	4.55	"	50	69.0	48.2	0.38	91
40	4.55	$Ni(NO_3)_2.6H_2O$	5	67.0	49.6	0.41	91
41	4.55	"	15	68.0	48.3	0.44	90
42	4.55	"	25	71.0	49.8	0.12	97
43	4.55	"	50	73.0	47.2	0.20	95
44	4.90	$Co(NO_3)_2.6H_2O$	5	52.0	61.6	0.91	82
45	4.90	"	15	59.0	55.9	0.87	84
46	4.90	"	25	51.5	59.1	1.12	78
47	4.90	"	50	53.5	55.4	1.20	76
48	4.90	$Fe(NO_3)_2.6H_2O$	5	48.0	60.3	1.31	74
59	4.90	"	15	51.0	60.1	1.14	78
50	4.90	"	25	49.5	63.1	1.08	80
51	4.90	"	50	44.5	60.6	1.52	70
52	4.55	$Cu(NO_3)_2.6H_2O$	5	81.0	40.4	0.42	90
53	4.55	"	15	85.5	41.6	0.11	97
54	4.55	"	25	76.0	44.2	0.33	92
55	4.55	"	50	77.0	46.2	0.14	97
56	4.90	$AgNO_3$	5	55.0	55.0	1.18	77
57	4.90	"	15	55.0	52.9	1.30	74
58	4.90	"	25	63.0	53.1	0.83	85
59	4.90	"	50	48.5	57.1	1.42	71
60	4.55	$Pb(NO_3)_2$	5	74.0	45.6	0.35	93
61	4.55	"	15	73.0	47.0	0.26	94
62	4.55	"	25	69.0	49.0	0.40	93
63	4.55	"	50	71.5	48.4	0.22	95
64	4.55	$Hg(NO_3)_2$.H2O	5	76.0	43.4	0.42	91
65	4.55	"	15	76.0	40.0	0.81	83
66	4.55	"	25	69.0	41.4	0.92	78
67	4.55	"	50	67.5	40.4	1.28	75
68	4.90	$UO_2(NO_3)_2.6H_2O$	5	51.0	58.6	1.20	76
69	4.90	"	15	49.5	59.1	1.22	75
70	4.90	"	25	41.0	53.1	2.31	56
71	4.90	"	50	18.0	31.7	4.17	12
72	4.55	$Al(NO_3)_3.9H_2O$	5	72.0	44.8	0.50	89
73	4.55	"	15	72.5	46.8	0.26	93
74	4.55	"	25	68.5	47.6	0.43	90
75	4.55	"	50	71.5	47.4	0.27	93

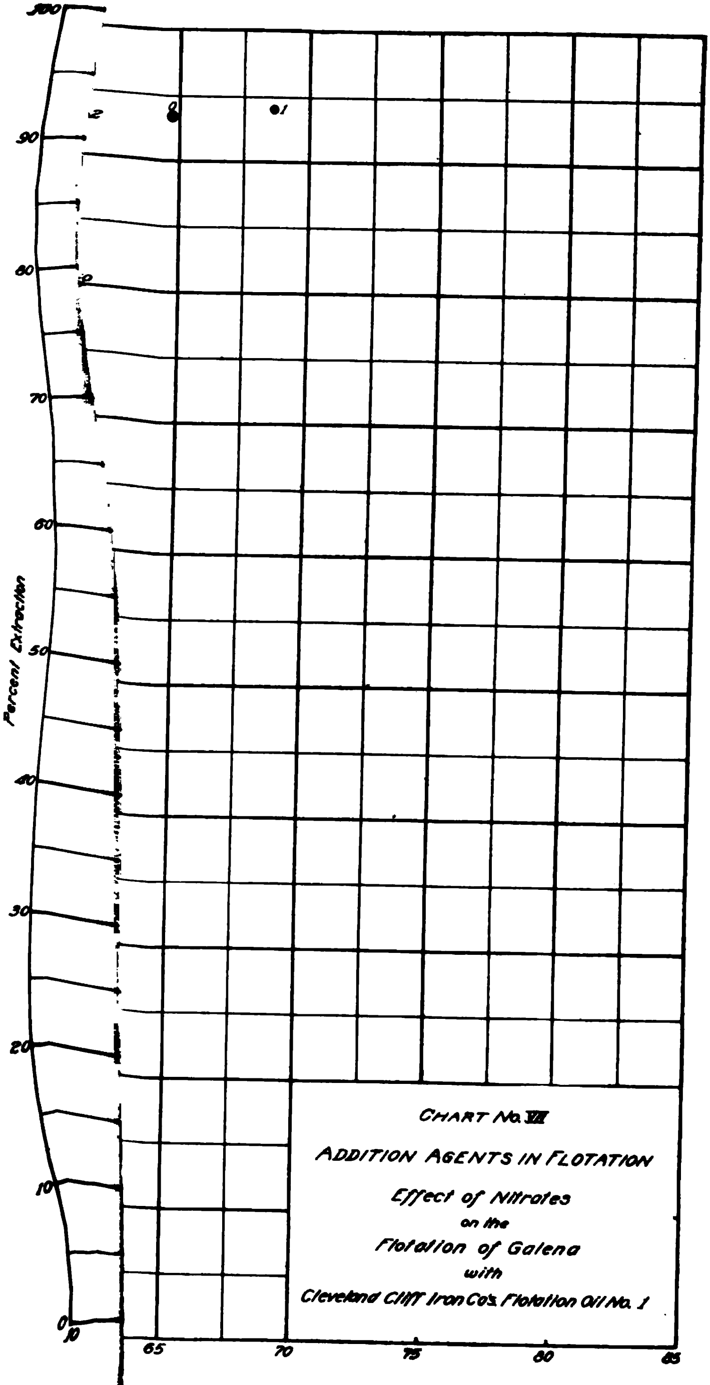

CHART No. VII

ADDITION AGENTS IN FLOTATION

Effect of Nitrates
on the
Flotation of Galena
with
Cleveland Cliff Iron Co's Flotation Oil No. 1

Test No.	Perc Le in F
32	4.
33	4.
34	4.
35	4.
36	4.
37	4.
38	4.
39	4.
40	4
41	4.
42	4.
43	4
44	4
45	4
46	4
47	4
48	4
59	4
50	4
51	4
52	4
53	4
54	4
55	4
56	4
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TABLE VII—(Cont.)

76	4.55	$Bi(NO_3)_3.5H_2O$	5	67.0	47.6	0.52	88
77	4.55	"	15	66.0	50.4	0.36	91
78	4.55	"	25	63.5	53.0	0.27	92
79	4.55	"	50	62.5	52.8	0.38	91
80	4.65	$Zn(NO_3)_2.6H_2O$	5	52.0	57.8	0.92	81
81	4.65	"	15	56.0	55.6	0.80	84
82	4.65	"	25	53.0	55.9	1.00	80
83	4.65	"	50	58.0	50.2	1.06	78
84	4.55	$Cd(NO_3)_2.4H_2O$	5	41.0	37.6	2.56	42
85	4.55	"	15	40.0	32.6	2.88	36
86	4.55	"	25	39.0	29.4	3.10	32
87	4.55	"	50	42.0	29.4	2.92	34

TABLE VIII

Oil, Cleveland Cliff Iron Co.'s Flotation Oil No. 1. Operating Data.
Amount used, 0.5 pound per ton. Time, 40 to 45 minutes.
Addition Agents, 5% Solution by Weight. Amount of water, 4000cc.
Dilution, 1 to 5. Amount of ore, 800 grams.
Speed of machine, 1700 r.p.m.

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
1	4.30	None	None	47.0	67.8	0.31	94
2	4.30	"	"	52.0	61.3	0.32	93
3	4.90	"	"	57.0	62.6	0.37	91
0	....	Average Oil	..	....	63.9	....	92.7
4	4.55	$Ba(NO_3)_2$	5	61.0	53.2	0.51	89
5	4.55	"	15	65.0	52.2	0.30	93
6	4.55	"	25	58.5	55.4	0.54	89
7	4.55	"	50	63.0	53.4	0.41	92
8	4.55	$Ca(NO_3)_2.4H_2O$	5	62.5	54.6	0.30	93
9	4.55	"	15	61.0	53.6	0.41	90
10	4.55	"	25	64.0	51.2	0.40	90
11	4.55	"	50	65.0	52.2	0.34	93
12	4.55	$Sr(NO_3)_2.4H_2O$	5	64.0	52.0	0.44	91
13	4.55	"	15	67.0	51.8	0.27	95
14	4.55	"	25	62.0	54.0	0.43	92
15	4.55	"	50	60.0	53.6	0.54	88
16	4.90	$Mg(NO_3)_2.6H_2O$	5	55.0	58.0	0.91	81
17	4.90	"	15	56.5	60.4	0.62	87
18	4.90	"	25	52.5	59.6	1.10	80
19	4.90	"	50	56.5	62.8	0.48	90
20	4.55	$NaNO_3$	5	59.0	54.8	0.47	89
21	4.55	"	15	64.0	51.4	0.39	90
22	4.55	"	25	61.0	55.4	0.30	93
23	4.55	"	50	61.5	53.2	0.42	90
24	4.55	KNO_3	5	63.0	53.4	0.40	92
25	4.55	"	15	63.5	52.8	0.31	92
26	4.55	"	25	62.5	53.4	0.36	92
27	4.55	"	50	62.0	53.6	0.43	91
28	4.90	NH_4NO_3	5	58.0	62.8	0.27	93
29	4.90	"	15	58.0	63.0	0.25	93
30	4.90	"	25	55.5	61.6	0.50	87
31	4.90	"	50	51.5	64.8	0.53	86
32	4.55	$LiNO_3$	5	66.5	50.2	0.40	92
33	4.55	"	15	60.5	54.2	0.44	90
34	4.55	"	25	63.5	54.8	0.18	95
35	4.55	"	50	64.0	50.2	0.51	88
36	4.90	$Mn(NO_3)_2.6H_2O$	5	60.0	52.4	1.02	80
37	4.90	"	15	60.0	58.4	0.61	89
38	4.90	"	25	58.0	61.3	0.47	91
39	4.90	"	50	59.0	58.2	0.63	88

TABLE VIII—(Cont.)

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
40	4.55	$Ni(NO_3)_2.6H_2O$	5	70.0	50.2	0.15	96
41	4.55	"	15	79.5	44.4	0.10	97
42	4.55	"	25	70.0	45.2	0.53	87
43	4.55	"	50	70.5	49.4	0.11	96
44	4.55	$Co(NO_3)_2.6H_2O$	5	56.5	60.2	0.31	93
45	4.55	"	15	61.0	55.7	0.28	93
46	4.90	"	25	65.0	53.8	0.50	89
47	4.90	"	50	60.0	55.8	0.72	85
48	4.90	$Fe(NO_3)_2.6H_2O$	5	57.0	58.8	0.70	86
49	4.90	"	15	58.5	57.2	0.72	86
50	4.90	"	25	58.5	63.2	0.33	94
51	4.90	"	50	58.0	61.4	0.43	91
52	4.55	$Cu(NO_3)_2.6H_2O$	5	67.0	52.6	0.11	97
53	4.55	"	15	68.0	52.2	0.10	97
54	4.55	"	25	73.0	47.4	0.20	95
55	4.55	"	50	66.0	52.2	0.25	94
56	4.55	$AgNO_3$	5	66.0	42.0	1.10	76
57	4.55	"	15	69.0	45.1	0.63	85
58	4.55	"	25	60.0	46.6	1.02	77
59	4.55	"	50	57.0	46.6	1.27	73
60	4.55	$Pb(NO_3)_2$	5	63.0	49.0	0.71	85
61	4.55	"	15	63.5	55.8	0.11	97
62	4.55	"	25	62.0	53.4	0.33	91
63	4.55	"	50	64.0	53.6	0.13	97
64	4.55	$Hg(NO_3)_2.H_2O$	5	68.0	43.0	0.85	80
65	4.55	"	15	69.5	42.6	0.81	86
66	4.55	"	25	63.5	43.6	1.04	76
67	4.55	"	50	56.0	43.8	1.31	67
68	4.90	$UO_2(NO_3)_2.6H_2O$	5	53.0	59.4	1.00	80
69	4.90	"	15	53.0	61.8	0.84	83
70	4.90	"	25	40.5	52.6	2.32	54
71	4.90	"	50	19.0	42.8	4.08	21
72	4.90	$Al(NO_3)_3.9H_2O$	5	62.0	54.4	0.75	86
73	4.90	"	15	56.5	56.0	0.96	82
74	4.90	"	25	57.5	61.2	0.42	90
75	4.90	"	50	62.5	57.9	0.36	92
76	4.90	$Bi(NO_3)_3.5H_2O$	5	52.0	62.8	0.81	83
77	4.90	"	15	53.5	61.4	0.92	81
78	4.90	"	25	47.5	58.8	1.47	71
79	4.90	"	50	38.0	53.8	2.43	52

TABLE VIII—(Cont.)

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
80	4.65	$Zn(NO_3)_2.6H_2O$	5	53.0	56.7	0.90	81
81	4.65	"	15	53.0	56.1	0.93	80
82	4.65	"	25	50.0	56.4	1.18	76
83	4.65	"	50	59.0	48.4	1.09	77
84	4.55	$Cd(NO_3)_2.4H_2O$	5	27.0	48.1	3.41	33
85	4.55	"	15	18.0	38.2	4.08	18
86	4.55	"	25	14.5	48.4	4.10	18
87	4.55	"	50	18.5	41.0	4.12	19

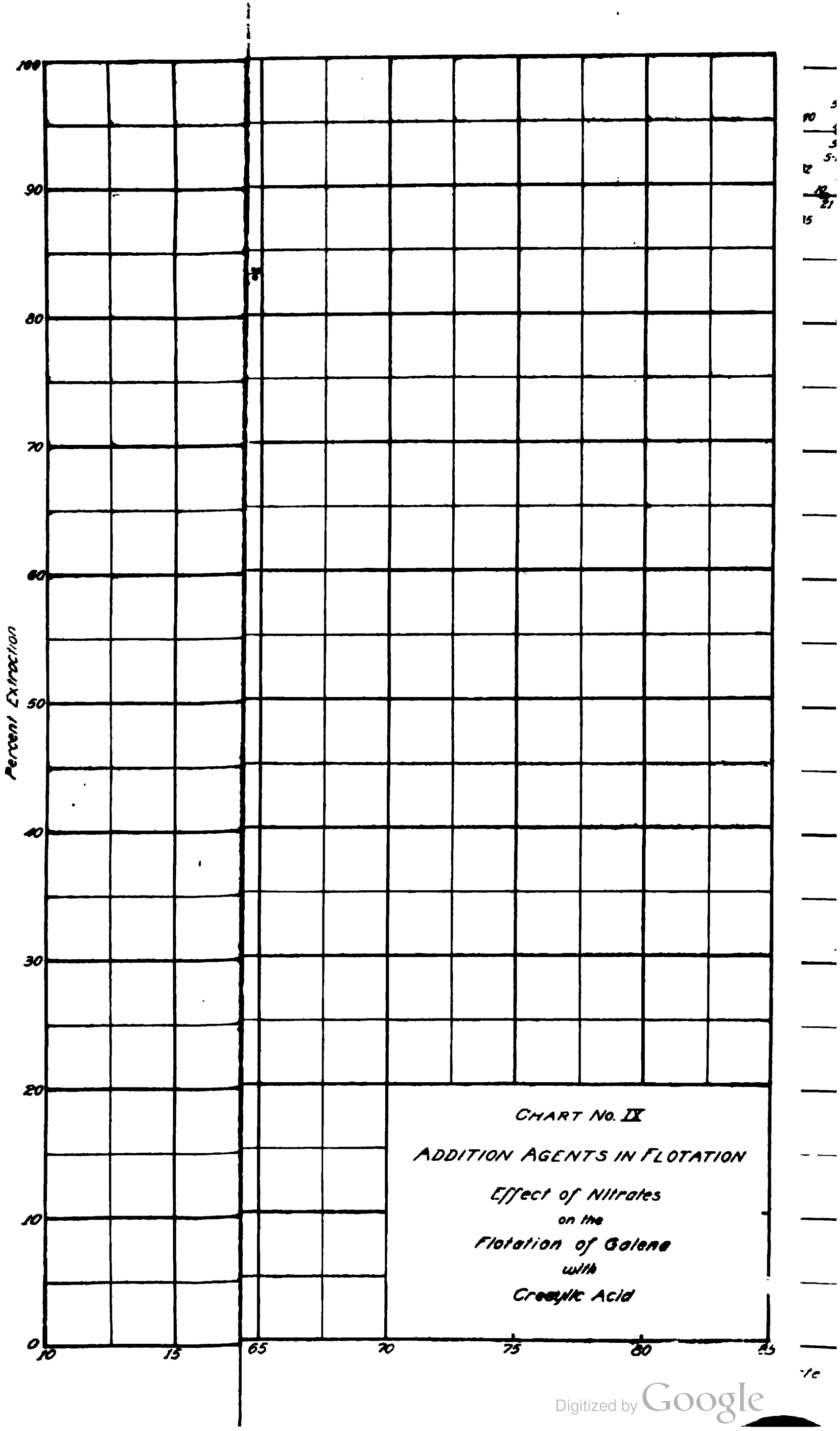

CHART No. IX

ADDITION AGENTS IN FLOTATION

Effect of Nitrates
on the
Flotation of Galena
with
Cresylic Acid

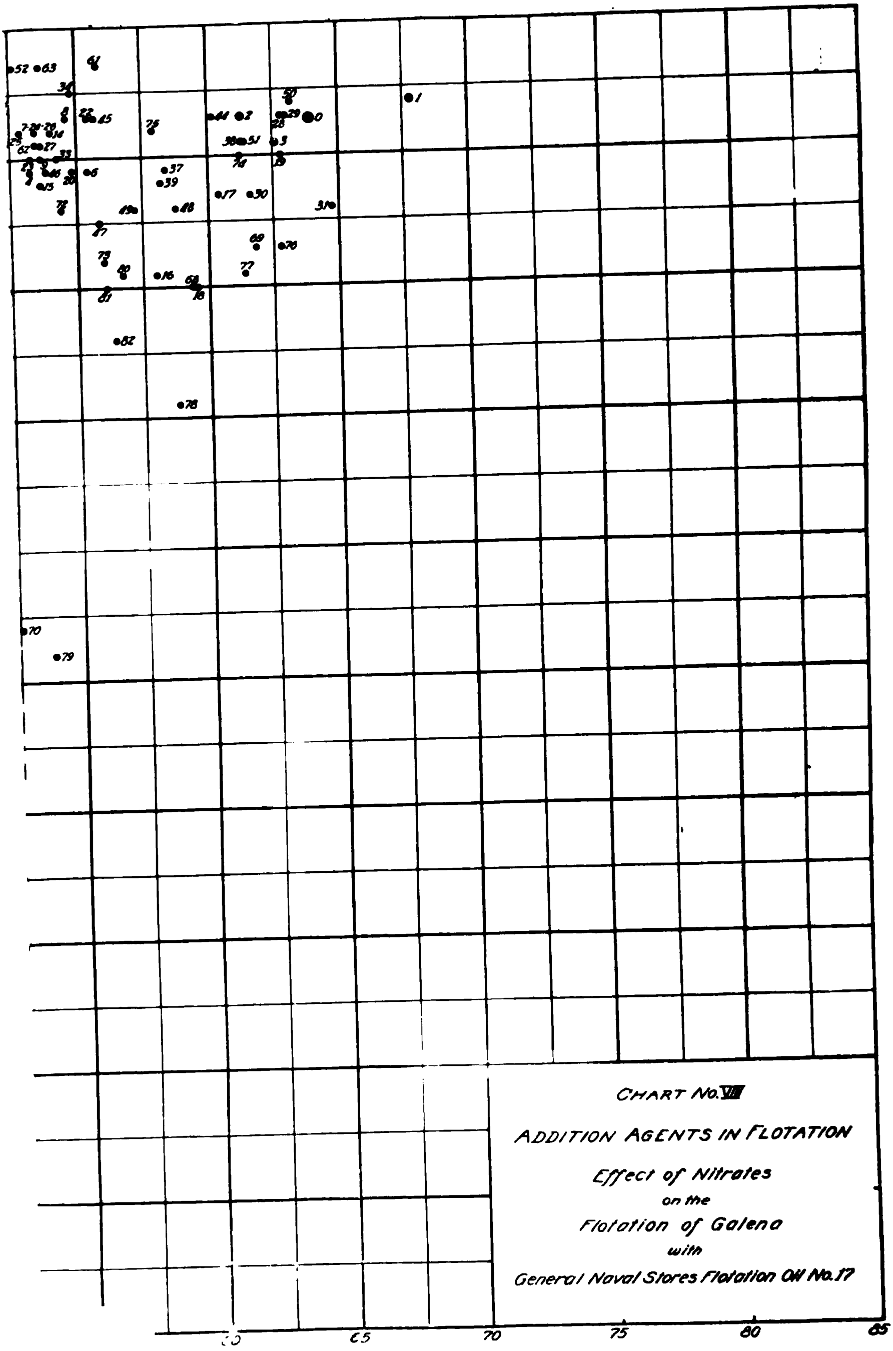

CHART No. VIII

ADDITION AGENTS IN FLOTATION

Effect of Nitrates
on the
Flotation of Galena
with
General Naval Stores Flotation Oil No. 17

TABLE IX

Oil, Cleveland Cliff Iron Co.'s Flotation Oil No. 1. Operating Data.
Amount used, 0.5 pound per ton. Time, 40 to 45 minutes.
Addition Agents, 5% Solution by Weight. Amount of water, 4000cc.
Dilution, 1 to 5. Amount of ore, 800 grams.
Speed of machine, 1700 r.p.m.

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
1	4.30	None	None	50.0	59.6	0.53	87
2	4.30	"	"	49.0	61.4	0.54	87
3	4.90	"	"	56.0	60.4	0.61	86
0	....	Average Oil	..	....	60.5	....	86.7
4	4.90	$Ba(NO_3)_2$	5	52.0	60.2	1.03	80
5	4.90	"	15	55.0	58.2	0.91	82
6	4.90	"	25	51.0	61.7	0.97	80
7	4.90	"	50	49.5	58.8	0.90	82
8	4.90	$Ca(NO_3)_2.4H_2O$	5	50.0	62.2	1.06	79
9	4.90	"	15	52.5	59.4	1.00	79
10	4.90	"	25	50.5	61.8	0.98	80
11	4.90	"	50	51.0	61.4	1.00	80
12	4.90	$Sr(NO_3)_2.4H_2O$	5	48.5	61.8	1.20	76
13	4.90	"	15	48.5	59.8	1.32	73
14	4.90	"	25	51.0	62.3	0.98	81
15	4.90	"	50	48.5	61.4	1.24	75
16	4.90	$Mg(NO_3)_2.6H_2O$	5	50.5	62.8	0.97	81
17	4.90	"	15	47.5	62.6	1.24	76
18	4.90	"	25	47.5	62.5	1.26	76
19	4.90	"	50	47.5	62.8	1.20	76
20	4.90	$NaNO_3$	5	51.5	64.2	0.77	84
21	4.90	"	15	55.0	62.1	0.61	87
22	4.90	"	25	51.0	62.2	0.92	81
23	4.90	"	50	49.0	59.4	1.23	74
24	4.90	KNO_3	5	49.0	59.6	1.26	75
25	4.90	"	15	49.0	63.4	1.08	79
26	4.90	"	25	47.0	61.8	1.28	74
27	4.90	"	50	48.0	59.6	1.36	73
28	4.90	NH_4NO_3	5	46.5	63.6	1.25	75
29	4.90	"	15	46.5	59.2	1.54	70
30	4.90	"	25	49.0	59.6	1.27	74
31	4.90	"	50	47.5	59.1	1.47	71
32	4.90	$LiNO_3$	5	50.0	62.4	1.03	80
33	4.90	"	15	52.0	64.2	0.73	85
34	4.90	"	25	51.0	63.4	0.87	83
35	4.90	"	50	50.0	62.8	1.00	80
36	4.90	$Mn(NO_3)_2.6H_2O$	5	51.0	63.5	0.82	83
37	4.90	"	15	52.0	63.1	0.80	84
38	4.90	"	25	50.0	64.8	0.82	83
39	4.90	"	50	50.5	64.4	0.84	83

TABLE IX—(Cont.)

Test No.	Percent Lead in Feed	Addition Agent		Concentrate		Tailings Lead %	Extraction %
		Kind	Amt. cc.	Wt. Gms.	Lead %		
40	4.90	$Ni(NO_3)_2.6H_2O$	5	49.5	63.6	0.97	81
41	4.90	"	15	58.0	57.6	0.75	85
42	4.90	"	25	50.0	63.6	0.94	81
43	4.90	"	50	55.0	59.4	0.82	83
44	4.90	$Co(NO_3)_2.6H_2O$	5	48.0	64.2	1.10	79
45	4.90	"	15	50.0	62.4	1.02	80
46	4.90	"	25	53.0	61.8	0.80	84
47	4.90	"	50	55.0	60.8	0.71	85
48	4.90	$Fe(NO_3)_2.6H_2O$	5	54.0	62.2	0.72	86
49	4.90	"	15	53.5	63.8	0.63	87
50	4.90	"	25	52.5	61.8	0.88	83
51	4.90	"	50	56.0	62.2	0.53	88
52	4.90	$Cu(NO_3)_2.6H_2O$	5	57.0	59.6	0.67	87
53	4.90	"	15	52.5	62.2	0.81	83
54	4.90	"	25	56.5	60.8	0.61	88
55	4.90	"	50	59.0	59.4	0.51	89
56	4.90	$AgNO_3$	5	48.0	59.6	1.37	73
57	4.90	"	15	46.5	47.6	2.36	54
58	4.90	"	25	32.0	46.8	3.12	38
59	4.90	"	50	26.0	37.2	3.63	25
60	4.90	$Pb(NO_3)_2$	5	48.0	63.6	1.15	78
61	4.90	"	15	50.0	61.6	1.08	79
62	4.90	"	25	50.0	62.8	1.00	80
63	4.90	"	50	52.0	61.8	0.86	81
64	4.90	$Hg(NO_3)_2.H_2O$	5	56.5	54.8	0.90	82
65	4.90	"	15	38.0	48.8	2.81	47
66	4.90	"	25	27.5	48.8	3.31	34
67	4.90	"	50	27.0	45.6	3.44	31
68	4.90	$UO_2(NO_3)_2.6H_2O$	5	39.0	61.8	1.93	61
69	4.90	"	15	31.0	52.2	2.94	41
70	4.90	"	25	22.5	45.2	3.73	26
71	4.90	"	50	21.0	37.8	3.88	23
72	4.90	$Al(NO_3)_3.9H_2O$	5	52.0	63.4	0.80	84
73	4.90	"	15	51.5	61.8	0.96	81
74	4.90	"	25	50.0	62.6	1.00	80
75	4.90	"	50	52.0	60.3	1.02	80
76	4.90	$Bi(NO_3)_3.5H_2O$	5	43.5	62.4	1.56	69
77	4.90	"	15	40.5	59.8	1.93	62
78	4.90	"	25	34.5	56.2	2.60	49
79	4.90	"	50	32.0	49.2	3.03	40

TABLE IX—(Cont.)

		Addition Agent		Concentrate		Tailings Lead %	Extraction %
Test No.	Percent Lead in Feed	Kind	Amt. cc.	Wt. Gms.	Lead %		
80	4.65	$Zn(NO_3)_2.6H_2O$	5	51.0	57.6	1.02	79
81	4.65	"	15	55.0	54.3	0.97	80
82	4.65	"	25	51.0	53.6	1.26	74
83	4.65	"	50	51.0	45.4	1.83	62
84	4.90	$Cd(NO_3)_2.4H_2O$	5	25.5	44.0	3.46	29
85	4.90	"	15	25.5	43.8	3.48	29
86	4.90	"	25	22.5	43.4	3.65	25
87	4.90	"	50	24.0	43.8	3.56	27

Alkaline Earth Nitrates

$Ba(NO_3)_2$. Nos. 4 to 7. Barium nitrate lowered the extraction about 4 per cent, regardless of the oil used. The effect of the grade of concentrate produced varied with the oil. Oil No. 1 lowered the lead tenor of the concentrate 18 per cent; oil No. 17 lowered the grade of the concentrate about 10 per cent; while with cresylic acid the concentrate was of practically the same grade as the one produced when no reagent was used.

The froths formed varied widely with this salt. With small quantities of barium nitrate, oil No. 1 gave a wet froth composed of medium-sized bubbles which broke slowly, while larger quantities of this reagent gave a dry froth composed of large bubbles. With oil No. 17 the froth was very wet and had a long life. Cresylic acid produced a wet ephemeral froth consisting of large bubbles, and the concentration was completed in 30 minutes.

$Ca(NO_3)_2.4H_2O$. Nos. 9 to 11. Calcium nitrate, when used with oils No. 1 and No. 17, had practically no effect on the extraction; but when used with cresylic acid the extraction was lowered about 7 per cent. The effect of this salt, when used with cresylic acid, on the grade of concentrate produced is practically nil, but when used with oils No. 1 and No. 17 the concentrate is lowered about 12 per cent.

The froths formed when using this reagent with oils No. 1 and No. 17 were composed of small, wet bubbles which broke readily. With cresylic acid the froth varied from small, wet bubbles, when small quantities of the reagent were used, to a dry, stiff froth with larger quantities.

$Sr(NO_3)_2.4H_2O$. Nos. 12 to 15. The effect of strontium nitrate on both the extractions and grade of concentrates produced was very similar to those of calcium nitrate, regardless of the oils used. The froths which formed were likewise very similar to those of the corresponding calcium salt, with the exception that they contained more water.

$Mg(NO_3)_2.7H_2O$. Nos. 16 to 19. Magnesium nitrate is very similar in all its effects to the corresponding calcium salt.

Summary. The alkaline earth nitrates gave very similar results, the general tendency being to lower slightly the extraction. The effect on the grade of concentrate produced seemed to depend more on the oil used than on any particular nitrate of this class or on the quantity of the nitrate used.

When used with oils No. 1 and No. 17, which produce a high grade concentrate without any reagent, the alkaline earth nitrates lowered the grade of concentrate very noticeably; but when used with cresylic acid, which has a tendency toward making a low-grade product, these nitrates have practically no effect on the concentrate produced.

Alkali Metal Nitrates

$NaNO_3$. Nos. 20 to 23. Sodium nitrate had practically no effect on the extraction when used with oils No. 1 and No. 17, but when used with cresylic acid the extraction is noticeably lowered. The effect on the grade of concentrate produced was just the opposite. The grade of concentrate with oil No. 1 was lowered about 16 per cent, with oil No. 17 about 8 per cent, while with cresylic acid the concentrate was of about the same grade as that produced when no reagent was present.

With oils No. 1 and No. 17 this salt gave a slow-forming froth, which was composed of small, wet bubbles which broke up slowly. With cresylic acid, sodium nitrate gave a dry, ephemeral froth, and the maximum extraction was obtained in 25 minutes

KNO_3. Nos. 24 to 27. Potassium nitrate, when used with oil No. 1 and cresylic acid, lowered the extraction more than did the corresponding sodium salt. With oil No. 17 it had practically no effect on the extraction. The lead tenor of the concentrate varied with the oil used, being slightly higher with cresylic acid and about 14 per cent lower with oils No. 1 and No. 17.

With oils No. 1 and No. 17 the addition of 5 cc. of potassium nitrate solution produced a froth consisting of large, wet bubbles. When larger quantities were used, the froth consisted of small, wet bubbles. With cresylic acid the froth formed slowly and consisted of large, dry bubbles which broke quickly.

$(NH_4)NO_3$. Nos. 28 to 31. Ammonium nitrate lowered the extraction slightly when used with oils No. 1 and No. 17, and considerably when used with cresylic acid. It had practically no effect on the grade of concentrate produced when used with oil No. 17 and cresylic acid, but with oil No. 1 it lowered the grade of concentrate about 12 per cent.

This reagent, when used with oils No. 1 and No. 17, gave a very wet froth, composed of small bubbles which broke quickly. With cresylic acid the froth was not so wet, and the concentration was completed in 25 to 30 minutes.

$LiNO_3$. Nos. 32 to 35. Lithium nitrate had little or no effect on the extraction. The lead content of the concentrate produced was about 16 per cent lower with oil No. 1, 12 per cent lower with oil No. 17, and 3 per cent higher with cresylic acid.

The froth formed when this salt was used varied with each oil. Oil No. 1 gave a wet froth, composed of medium-sized bubbles; oil No. 17 gave a froth similar to oil No. 1, except that the bubbles were much smaller. Cresylic acid gave a dry, ephemeral froth, composed of medium-sized bubbles, and the concentration was completed in about 25 minutes.

Summary. When the alkali metal nitrates are considered as a group, the results obtained correspond so closely with those obtained with the alkaline earth nitrates that further discussion is unnecessary.

Metallic Nitrates

$Mn(NO_3)_2.6H_2O$. Nos. 36 to 39. Manganese nitrate lowered the extraction about 3 per cent, regardless of the oil used. The grade of concentrate was lowered about 16 per cent with oil No. 1, and about 4 per cent with oil No. 17, but with cresylic acid the concentrate was raised about 3 per cent.

The froth formed varied with the oil used. Oil No. 1 gave a wet froth consisting of small bubbles; oil No. 17 gave a wet, ephemeral froth made up of medium-sized bubbles, and cresylic acid gave a dry, ephemeral froth composed of large bubbles.

$Ni(NO_3)_2.6H_2O$. Nos. 40 to 43. Nickel nitrate had practically no effect on the extraction when used with any one of the three oils. The grade of concentrate varied with the oil. When oil No. 1 was used the concentrate was lowered about 16 per cent, with oil No. 17 about 14 per cent, while the concentrate formed when cresylic acid was used was of about the same grade as that obtained when no reagent was present.

Oils No. 1 and No. 17, when used with 5 cc. of this salt, produced an ephemeral froth composed of very small bubbles. When larger quantities of the reagent were added, these oils produced a froth composed of very large bubbles which had an exceptionally long life. Cresylic acid gave a dry, ephemeral froth composed of large bubbles.

$CO(NO_3)_2.6H_2O$. Nos. 44 to 47. With cobalt nitrate and oil No. 1 the extraction was lowered about 13 per cent. The effect of this salt is so nearly like the effect of nickel nitrate in all other respects that further discussion is unnecessary.

$Fe(NO_3)_2.6H_2O$. Nos. 48 to 51. The extractions obtained when ferrous nitrate was used varied more with the oil than with the quantity of the reagent added. With this salt and oil No. 1 the extraction was lowered about 17 per cent, with oil No. 17 only 4 per cent, while with cresylic acid the extraction is practically the same as when no reagent was present. The effect on the grade of concentrate produced was very slight. With oils No. 1 and No. 17 the concentrate was lowered about 3 per cent; with cresylic acid it was raised about 2 per cent.

The froths formed were very similar to those formed when nickel nitrate was used.

$Cu(NO_3)_2.6H_2O$. Nos. 52 to 55. Copper nitrate had practically no effect on the extraction when used with any one of the three oils. The effect on the grade of concentrate produced varied with the oil used. Oil No. 1 produced a concentrate which contained 22 per cent less lead than that obtained without a reagent. Oil No. 17 gave a 13 per cent lower grade concentrate while cresylic acid gave a concentrate having practically the same composition as that obtained when no reagent was present.

The froth formed when copper nitrate was used with oil No. 1 consisted of very small, wet bubbles. Oil No. 17, when used with this salt, produced a froth composed of wet medium-sized bubbles, while cresylic acid produced a froth of very large dry bubbles.

$AgNO_3$. Nos. 56 to 59. The results obtained when silver nitrate was used varied greatly. With oils No. 1 and No. 17 some of the extractions were lower than others, but this variation did not occur uniformly as the amount of silver nitrate solution was increased. With oil No. 1 the extractions varied from 10 per cent to 25 per cent low, while with oil No. 17 they varied from 8 per cent to 19 per cent low. The lead tenor of the concentrates with oil No. 1 was lowered about 10 per cent, while with oil No. 17 the grade of concentrate varied from 16 per cent to 20 per cent low.

When cresylic acid was used, both the extraction and grade of concentrate were lowered in accordance with the amount of silver nitrate present. When 5 cc. of the salt was present the extraction was lowered 14 per cent, while the lead tenor of the concentrate was lowered only 1 per cent. But when 50 cc. of the reagent was added the extraction was lowered 62 per cent and the lead tenor of the concentrate 23 per cent. These results, when plotted, show a fair curve in which the extraction and grade of concentrate fall as the amount of silver nitrate is increased.

The character of the froths formed when silver nitrate was used varied widely. With oil No. 1 small amounts of this salt produced an extremly wet froth, but when the maximum amount of the salt was added the froth was exceedingly dry and very stiff. With oil No. 17 the froths were not as extreme as were those with the preceding oil. Cresylic acid produced dry, ephemeral froths composed of large bubbles which seemed to have very little carrying power.

$Pb(NO_3)_2$. Nos. 60 to 63. Lead nitrate, when used with oils No. 1 and No. 17, had no effect on the extraction, but when used with cresylic acid the extraction was lowered about 7 per cent. The concentrate produced follows the usual order, being about 17 per cent low with oils No. 1 and No. 17, and 2 per cent or 3 per cent high with cresylic acid.

The froths formed when this salt was used likewise follow the usual order—small, wet bubbles with oil No. 1 to large, dry bubbles with cresylic acid.

$Hg(NO_3)_2.H_2O$. Nos. 64 to 67. Generally speaking, mercuric nitrate had a detrimental effect both on the extraction and the grade of concentrate produced, regardless of the oil used. When used with oil No. 1, the extraction was lowered about 10 per cent and the grade of concentrate about 22 per cent. When used with oil No. 17 the extraction was lowered about 18 per cent and the grade of concentrate 20 per cent. When used with cresylic acid the effect on both the extraction and grade of concentrate is almost identical with the effect produced by silver nitrate.

The froths produced by mercuric nitrate were all wet and varied only in the amount of water they contained.

$UO_2(NO_3)_2.6H_2O$. Nos. 68 to 71. Uranyl nitrate is another reagent which has a very detrimental effect both on the extraction and grade of concentrate produced. Its effect is very similar with all three oils in that as the amount of uranyl nitrate solution was increased the extraction and the grade of concentrate were lowered.

There also seemed to be a relation between the character of froth formed and the extraction in that the more water the froth contained the poorer the extraction. The froths formed very slowly, were very light, broke down quickly, and seemed to have no carrying power.

$Al(NO_3)_3.9H_2O$. Nos. 72 to 75. The effect of aluminum nitrate is practically the same as manganese nitrate, hence no further discussion is necessary.

$Bi(NO_3)_3.5H_2O$. Nos. 76 to 79. Bismuth nitrate, when used with oil No. 1, lowered the extraction about 5 per cent and the grade of concentrate about 15 per cent. When used with oil No. 17 and cresylic acid, both the extractions and the grade of concentrates were lowered as the amount of the salt was increased.

All the froths formed consisted of small, wet bubbles.

$Zn(NO_3)_2.6H_2O$. Nos. 80 to 83. Zinc nitrate lowered the average extraction about 12 per cent, and the grade of concentrate averaged about 8 per cent to 9 per cent low.

The froths formed varied from small, wet bubbles to large, dry bubbles, depending on the quantity of reagent added and the oil used.

$Cd(NO_3)_2.4H_2O$. Nos. 84 to 87. Cadmium nitrate, like cadmium sulphate, had a very pronounced effect on the extraction and grade of concentrate in that both were lowered enormously. When cadmium sulphate was used there seemed to be a marked relation between the amount of the salt present and the results obtained, but when cadmium nitrate was used this relation was not brought out so forcibly.

The froths formed with oil No. 1 and this nitrate were very wet, while with cresylic acid they were dry.

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Summary of Effect of Nitrates

The nitrates used, when considered as a whole, gave widely divergent results, which seemed to depend more on the oil than on any other factor.

When oil No. 1 was used the average extraction, with a few exceptions, was practically the same as when the oil was used without any reagent, but the average grade of concentrate produced was lowered about 17 per cent.

When oil No. 17 was used the average extraction was lowered slightly, while the grade of concentrate was lowered from 8 per cent to 10 per cent.

With cresylic acid the average extraction was lowered about 7 per cent, but the grade of concentrate produced was raised 2 per cent or 3 per cent.

The nitrates had a very striking effect on the character of the froth formed. When used with oil No. 1 the froth was usually composed of small, wet bubbles. In a few cases the bubbles were so small that the froth resembled a thick scum.

When oil No. 17 was used the bubbles were larger and the froth was not so wet as that produced with oil No. 1.

When cresylic acid was used the froth was usually dry and was composed of large bubbles which seemed to have very little carrying power.

REFERENCES

The following is a brief resume of some of the literature on the use of addition agents in flotation. It includes only a very few of the articles on the subject and does not pretend to be a complete list of even the more important references. It has seemed worth while, however, to gather the material together in this connection.

It will be noted that many patents on preferential flotation are based on the use of some addition agent which tends to separate one sulphide from another.

Flotation at the Consolidated Arizona Smelting Co., Humboldt, Ariz. (Editorial correspondence.) *Metallurgical and Chemical Engineering*, vol. 13, pp. 897-901. Dec. 1, 1915.

The grade of concentrate in the flotation plant suddenly deteriorated. Tests showed that cement was the cause ot the trouble.

Some notes on flotation.—R. C. Canby. *Engineering and Mining Journal*, vol. 112, pp. 29-30. July 1, 1916.

"At Teziutlan I found that acid was necessary to cause the zinc to float. I found, however, that the actual presence of acid during flotation was not necessary, but that if the ore was given an acid treatment and then washed thoroughly upon a filter until no trace of acid was discernible, the same result was obtained as though the acid had not been washed off."

Notes on flotation.—Rudolph Gahl. *Mining and Scientific Press,* vol. 113, pp. 460-62. Sept. 23, 1916.

The author presents a table of results and states that "the laboratory experiments proved conclusively that iron had a beneficial influence on flotation in counteracting the harmful effect of the primary slime." The iron was added in the form of iron filings.

Flotation of copper ores.—J. M. Callow. *Mining and Scientific Press,* vol. 110, pp. 826-28. May 29, 1915.

"Some ores work best in an alkaline pulp and others in a neutral one. My own opinion is, that in most cases the same results can be obtained in alkaline or neutral pulp as can be obtained in an acid one, and the advantage of an alkaline or neutral pulp is self-evident.

"In one plant we had an interesting experience of this kind. The water supply was limited and all the milling-water was returned to the mill. The flotation results gradually deterorated as the mill-water accumulated acid; the more acid it got, the poorer the results. Lime was then added in the tube-mill and the pulp made alkaline. This produced a tremendous increase in the volume of froth made, but without any definite improvement in the tailing. By reducing the lime and allowing the pulp to work back to the neutral point, the results became normal; and it is at the neutral point we now do our best work."

How flotation works.—G. O. Van Arsdale. *Engineering and Mining Journal,* vol. 101, pp. 851-55. May 13, 1916.

"There are a number of other substances besides sulphuric acid, having the property of preventing or destroying emulsions. Sulphuric, cresylic, acetic and citric acids entirely prevent emulsification. Aluminum sulphate and copper sulphate prevent emulsification. Ferrous sulphate and caustic soda have no action. Sodium chloride stabilizes and increases emulsification."

Recent progress in flotation.—O. C. Ralston and F. Cameron. *Engineering and Mining Journal,* vol. 99, pp. 937-40. May 29, 1915.

"The addition of acid seems to improve selective action, especially on galena, sphalerite and pyrite, and appears to be effective for the purpose of getting clean concentrate with a minimum gangue. The removal of oxidized films from sulphide particles is one result. In other instances it has been found that the presence of acid is fatal to the process. The presence of any electrolyte seems to have a marked effect on flotation."

Separation and classification of the metallic constituents of ore from gangue. *U. S. Patent* 763,259 and 763,260. Arthur E. Cattermole. June 21, 1904.

"Relates to the classification of the metalliferous constituents of ores, which have been separated from gangue by oil or similar matter," and "consists in fractionally removing the different constituents in turn from oil, by the use of emulsifying agents of varying strength and activity, preferably in conjunction with an alkali." "In carrying out the process, the metalliferous matter agglomerated by oil is mixed and agitated with a solution of an emulsifying agent, such as a soluble soap—alkaline oleate, for example—to which a certain proportion of soluble alkali, preferably caustic potash or soda, has been added."

Separation of metallic sulphide ores; Concentration of ores *U. S. Patent* 1,203,372 - 375. Fleury J. Lyster. October 31, 1916.

The Lyster process is carried on in neutral or alkaline solutions (never acid) of the sulphates, chlorides, or nitrates of calcium, magnesium, sodium, potassium, or of their mixtures, or solutions of manganese, zinc, iron, acid sodium, or sodium-potassium sulphates.

Preferential flotation of minerals from mixed sulphide ores. *U. S. Patent* 1,102,738. H. H. Greenway and H. P. Lowry. Australia. July 7, 1914.

If a salt of chromium (such as sodium bichromate or potassium bichromate) is introduced in solution into the circuit liquors, or if the material to be treated is subjected to the action of such a chromium salt solution by digestion or otherwise, the sulphides are affected in such a way as to leave certain of them amenable to flotation, whereby products are obtained relatively high in certain sulphides on the one hand and relatively high in the other sulphides on the other.

Preferential flotation of galena and blende. *U. S. Patent* 1,142,821. Henry Lavers, Australia. June 15, 1915.

The results obtained by the use of sodium or potassium bichromate are greatly improved if the water is made slightly alkaline, as by the use of sodium carbonate equivalent to 1 per cent by weight of the ore.

Preferential flotation of galena and blende. *U. S. Patent* 1,157,176. Thomas M. Owen, Australia. October 19, 1915.

The addition of minute quantities of potassium permanganate to slime which contains a mixture of lead and zinc sulphides will permit a separate flotation of the two minerals.

Preferential flotation. *English Patent* 21,104 of 1913. Leslie Bradford, Australia.

The ores or ore products are treated in a medium which wets zinc sulphide and does not wet lead sulphide or pyrite, and therefore leaves the last named sulphides amenable to flotation, while rendering the zinc sulphide temporarily immune to flotation. The "wetting" effect is procured by adding certain mineral salts, such as thiosulphates, sulphites and bisulphites, to a solution of sulphuric acid, thus decomposing the salts and producing sulphur dioxide.

Part II will be published as a forthcoming Bulletin of the Technical Series, and will discuss the effect of chlorides, acetates, oxalates, manganates, carbonates, bromides and other salts.

BULLETINS OF THE MISSOURI SCHOOL OF MINES

General Series

Vol. 1, No. 1, Dec., 1908. The human side of a mining engineer's life. Edmund B. Kirby. (Commencement address, June 10, 1908.)

Vol. 1, No. 2, 38th Annual Catalogue, 1909-1910.

Vol. 1, No. 3, June, 1909. Education for utility and culture. Calvin M. Woodward. (Tau Beta Pi address.)

Vol. 1, No. 4, Sept., 1909. The history and development of the cyanide process. Horace Tharp Mann.

Vol. 2, No. 1, Dec.. 1909. The Jackling field, School of Mines and Metallurgy.

Vol. 2, No. 2, 39th Annual Catalogue, 1910-1911. *(Out of print.)*

Vol. 2, No. 3, June, 1910. Some of the essentials of success. Charles Summer Howe. (Commencement address, June 1, 1910.)

Vol. 2, No. 4, Sept., 1910. Friction in small air pipes. E. G. Harris, Albert Park, H. K. Peterson. (Continued by Technical Series. Vol. 1, Nos. 1 and 4.)

Vol. 3, No. 1, Dec., 1910. Some relations between the composition of a mineral and its physical properties. G. H. Cox, E. P. Murray.

Vol. 3, No. 2, March 1, 1911. 40th Annual Catalogue, 1911-1912.

Vol. 3, No. 3, June, 1911. Providing for future generations. E. R. Buckley. (Tau Beta Pi address, May 24, 1911.)

Vol. 3, No. 4, Sept., 1911. Fall announcement of courses. *(Out of print.)*

Vol. 4, No. 1, Dec., 1911. Fortieth anniversary of the School of Mines and Metallurgy of the University of Missouri. Parker Hall Memorial address. Laying of cornerstone of Parker Hall, Rolla, Missouri, October 24, 1911.

Vol. 4, No. 2, March, 1912. 41st Annual Catalogue, 1912-1913.

Vol. 4, No. 3, June, 1912. Mining and civilization. J. R. Finlay. (Commencement address, May 31, 1912.)

Vol. 4, No. 4 Sept., 1912. Fall announcement of courses. *(Out of print.)*

Vol. 5, No. 1, Dec., 1912. Student Life.

Vol. 5, No 2, March, 1913. 42nd Annual Catalogue, 1912-1913.

Vol. 5, No 3. Never published.

Vol. 5, No 4. Never published.

Vol. 6, No 1. Never published.

Vol. 6, No. 2, March, 1914. 43rd Annual Catalogue, 1913 1914.

Vol. 6, No 3. Never published.

Vol. 6, No. 4. Never published.

Vol. 7, No. 1. Never published.

Vol. 7, No. 2, March, 1915. 44th Annual Catalogue, 1914-1915.

Vol. 7, No. 3, June, 1915. Description of special courses in oil and gas and allied subjects.

Vol. 7, No. 4, Sept., 1915. Register of graduates, 1874-1915.

Vol. 8, No. 1, Jan., 1916. Bibliography on concentrating ores by flotation. Jesse Cunningham.

Vol. 8, No. 2, March, 1916. 45th Annual Catalogue, 1915-1916.

Vol. 8, No. 3, June, 1916. The business of mining. W. R. Ingalls. (Commencement address, May 26, 1916.)

Vol. 8, No. 4, Oct., 1916. Register of graduates, 1874-1916. *(Out of print.)*

Vol. 9, No. 1, Jan., 1917. Road problems in the Ozarks. E. G. Harris. Bibliography on rural roads. H. L. Wheeler.

Vol. 9, No. 2, March, 1917. 46th Annual Catalogue, 1916-1917.

Vol. 9, No. 3, June, 1917. What should a present-day metallurgical education comprise? Charles Hermann Fulton. (Commencement address, May 25, 1917.)

Vol. 9, No. 4, Oct., 1917. Register of graduates, 1874-1917. M. S. M. men in military service.

Technical Series

Vol. 1, No. 1, Nov., 1911. Friction in air pipes. E. G. Harris. (Continuation of General Series, Vol. 2, No. 4.)

Vol. 1, No. 2, Feb., 1912. Metallurgy and ore dressing laboratories of the Missouri School of Mines and Metallurgy. D. Copeland, H. T. Mann, H. A. Roesler. *(Out of print.)*

Vol. 1, No. 3, May, 1912. Some apparatus and methods for demonstrating rock drilling and the loading of drill-holes in tunneling. L. E. Young.

Vol. 1, No. 4, Aug., 1912. Friction in air pipes. E. G. Harris. (Continuation of Vol. 1, No. 1, Nov., 1911.)

Vol. 2, No. 1, Aug., 1915. Comparative tests of piston drill-bits. C. R. Forbes and L. M. Cummings.

Vol. 2, No. 2, Nov., 1915. Orifice measurements of air in large quantities. Elmo G. Harris.

Vol. 2, No. 3, Feb., 1916. Cupellation losses in assaying. Horace T. Mann and Charles Y. Clayton.

Vol. 2, No. 4, May, 1916. Geologic criteria for determining the structural position of sedimentary beds. G. H. Cox and C. L. Dake. *(Out of print.)*

Vol. 3, No. 1, Aug., 1916. Experiments from the flotation laboratory. C. Y. Clayton. *(Out of print.)*

Vol. 3, No. 2, Nov., 1916. Studies on the origin of Missouri cherts and zinc ores. G. H. Cox, R. S. Dean and V. H. Gottschalk.

Vol. 3, No. 3, Feb., 1917. Preliminary report on blended Portland cement. E. S. McCandliss.

Vol. 3, No. 4, May, 1917. Studies in the production of oils and tars from bituminous materials. J. C. Ingram.

Vol. 4, No. 1, Aug., 1917. The hydrometallurgy and electrolytic precipitation of zinc. F. D. James.

Vol. 4, No. 2, Nov., 1917. The effect of addition agents in flotation. Part I. M. H. Thornberry and H. T. Mann.

Vol. 4, No. 3, Feb., 1918. Bibliography: Roasting, leaching, smelting, electric smelting and electrolysis of zinc. H. L. Wheeler. *(In preparation.)*

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Volume Four Number Three

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

BULLETIN

FEBRUARY, 1918

TECHNICAL SERIES

A BIBLIOGRAPHY
on the
ROASTING, LEACHING, SMELTING
and
ELECTROMETALLURGY OF ZINC

REVISED TO JUNE, 1919.

ROLLA, MISSOURI
1918

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THE EXPERIMENT STATION

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Martin Harmon Thornberry, B. S... *Research Assistant*
Walter Jay Mann.................. *Station Assistant*

The Experiment Station was established June 1, 1909.

It is the object of the Station to conduct such original researches or to verify such experiments as relate to the properties and uses of mineral products; to investigate the engineering problems connected with the mineral industry, the economic methods of mining and the preparation of mineral products, the methods of preventing waste of the mineral resources and the methods of preventing accidents in mines, mills, and smelters, to assist in improving the conditions surrounding the labor in mines, mills, and smelters; and such other researches or experiments as bear directly upon the application of mining and metallurgical engineering to the mineral industry of the State of Missouri.

Any resident of the State may on request obtain bulletins as issued, or if particularly interested, may be placed on the regular mailing list. Correspondence regarding these bulletins or the work of the Station may be addressed to the Director, Mining Experiment Station, Rolla, Missouri.

SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

A BIBLIOGRAPHY
on the
ROASTING, LEACHING, SMELTING
and
ELECTROMETALLURGY OF ZINC

Compiled by
Harold L. Wheeler, A. B., B. L. S.,
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ROLLA, MISSOURI
1918

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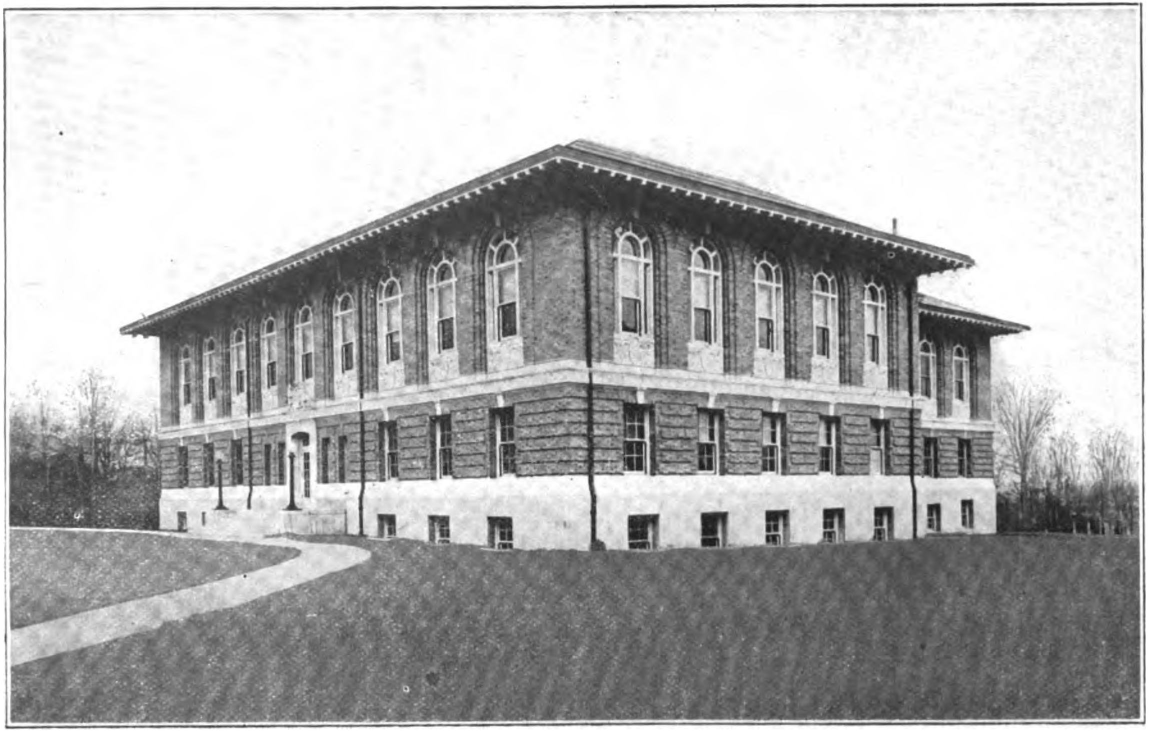

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[4] 1916-17; Absent since May, 1917; Sergt., 270th Aero Squadron, A. E. F.

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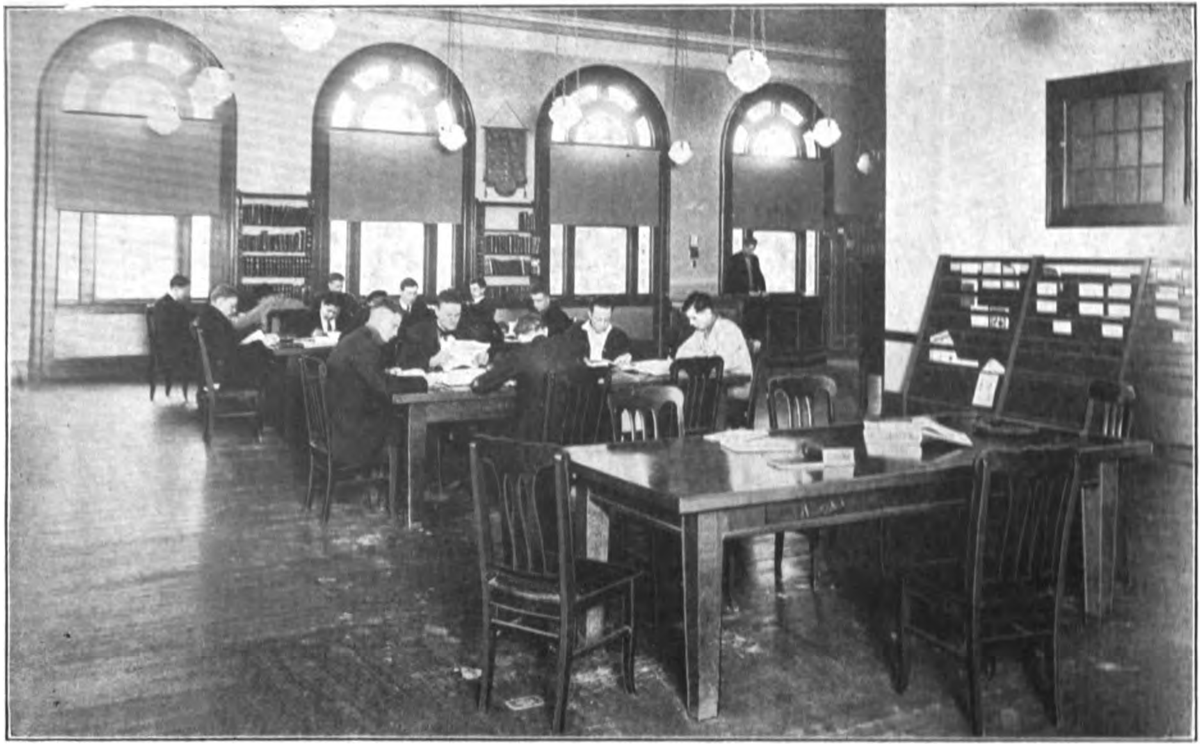

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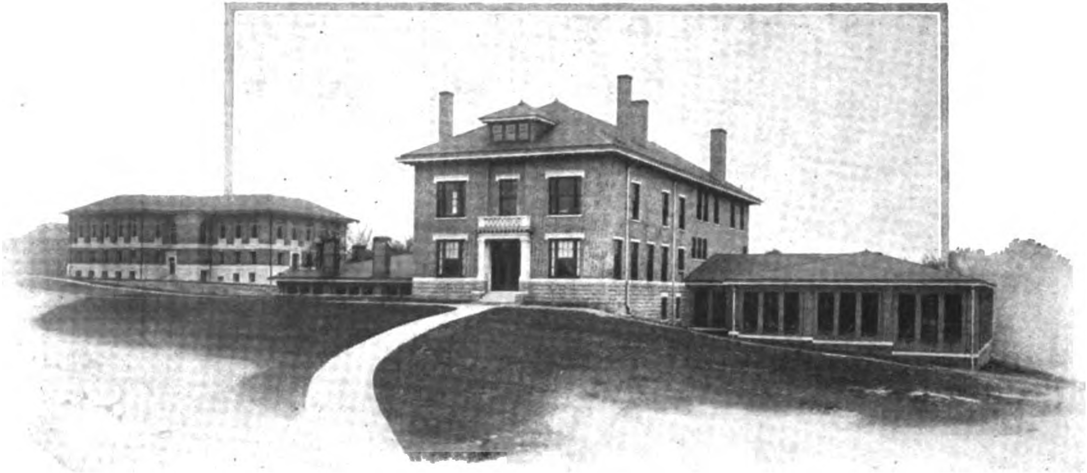


METALLURGY AND ORE DRESSING BUILDING

PREFACE

The following list of references was compiled chiefly for the use of the instructors and students in the Metallurgy Department of the Missouri School of Mines, and is based on the collection of material in the Library of the School, although fully half its references are to material not in this Library. It is not, therefore, a complete bibliography, although the effort has been to make it as nearly so as was possible with the resources and the time available, and the compiler believes that it may be considered reasonably complete. The amount of literature on the metallurgy of zinc is enormous, especially in the case of patents. It has been the intention, therefore, to omit material of minor importance and to emphasize processes rather than apparatus. The files of foreign patents are not among the resources of this Library, and are available only through abstracts and citations in other journals. For this reason the inclusion of foreign patents is especially incomplete.

In the case of the United States patents, the descriptive annotations are quoted from the patent claims as printed in the official Patent Office Gazette. For each patent not more than one claim is quoted, although usually the Gazette gives several. When the number of claims in the Gazette exceeds four or five, the fact is stated in the bibliography. In quoting patent claims the phraseology *and punctuation* of the Gazette have been followed; but the compiler has abandoned the Gazette's use of "sulfid" for "sulphide", and other examples of "reformed" spelling, both for the sake of uniformity with the rest of the bibliography, and because he considers "sulfid" no more excusable than "filosofy".

The work on the bibliography was undertaken in March, 1917, and concluded early in November, 1918. From that date until March, 1919, the compiler was on leave of absence, in charge of the Cantonment Library at Camp A. A. Humphreys, Va., so that the final details of preparing the manuscript for the printer were attended to by Miss Irish, the Assistant Librarian. Additions have been made in the proof-sheets, so as to include material which has been published or received in this country up to June, 1919.

The compiler is indebted to Mr. Russell B. Caples, '10, Assistant Superintendent of the Zinc Plant of the Anaconda Copper Mining Co., for the two illustrations of that plant; to Dr. Charles H. Fulton, Professor of Metallurgy at the Case School of Applied Science, for the photographs showing his electric smelting furnace and its work; to Mr. Ross Bowles, Superintendent of the American Zinc Co. of Illinois, for views of the zinc works of that company; to Mr. H. F. Bradley, Chief Chemist of the Judge Mining & Smelting Co., for illustrations of the electrolytic zinc plant at Park City, Utah; and to the St. Louis Section of the American Institute of Mining and Metallurgical Engineers for the three illustrations used on pages 200 and 346.

Mr. W. R. Ingalls, editor of the Engineering and Mining Journal, very kindly extended permission to use the two maps showing the smelting centers of Belgium and Silesia, which have been redrawn, with slight changes, from the Engineering and Mining Journal, in which they were originally published. The map showing the zinc industry of the United States is here published by courtesy of the U. S. Geological Survey, as are also the lists of smelting and electrolytic plants. The map and the lists were revised to January 1, 1919, by Mr. C. E. Siebenthal, of the Survey.

This bibliography was first suggested by Mr. Floyd D. James, of the Mining Experiment Station, in connection with certain investigations which were later published in his Bulletin on the Hydrometallurgy and Electrolytic Precipitation of Zinc. To him the compiler is indebted for many helpful suggestions.

Thanks are due Mr. Nelson W. McCombs of the Library School of the New York Public Library for valuable assistance in searching and verifying, at the New York Public Library and the Library of the United Engineering Societies, a large number of references to journals which are not in the Library of the Missouri School of Mines, and were not accessible to the compiler.

To Professor Horace T. Mann, of the Metallurgy Department, the compiler is especially grateful for much kindly encouragement, and for frequent and valuable assistance.

All the members of the Library staff, including those now absent, have assisted in the preparation of this bibliography. Their interest and willing spirit have helped materially to lighten the labor of its compilation.

LIST OF JOURNALS TO WHICH REFERENCES HAVE BEEN MADE, AND ABBREVIATIONS USED.

Amer. Chem. Jour.
American Chemical Journal, Baltimore. In 1914 incorporated with the Journal of the American Chemical Society.

Amer. Electrochem. Soc., Trans.
American Electrochemical Society, Transactions, Philadelphia and South Bethlehem, Pa.

Amer. Inst. Min. Eng., Trans., and Bull.
American Institute of Mining Engineers, Transactions, and Bulletin, New York.

Amer. Min. Cong., Rept.
American Mining Congress, Reports of annual meetings.

Ann. Chim. Anal.
Annales de Chimie Analytique et Revue de Chimie Analytique, Paris.

Ann. de Chim. et Phys.
Annales de Chimie et de Physique, Paris. Since 1914 in two separate series.

Annales des Mines.
Annales des Mines. Paris.

Ann. der Phys. und Chem.
Annalen der Physik und Chemie, Leipzig. Continued since 1899 as Annalen der Physik.

Atti R. Accad. Lincei.
Atti delle Reale Accademia dei Lincei, Rome.

Austral. Min. Stand.
Australian Statesman and Mining Standard, Melbourne and Sidney Since 1918 the Industrial Australian and Mining Standard.

Berg- u Huetten. Zeitg.
Berg- und huettenmaennische Zeitung, Leipzig. In 1904 was incorporated with Glueckauf.

Berichte der Deutsch. Chem. Gesell.
Berichte der Deutschen Chemishen Gesellschaft, Berlin.

Bull. de l'Assoc. Belge des Chim.
Bulletin de l'Association Belges des Chimistes, Gand. Since 1904 known as the Bulletin de la Societe Chimique de Belgique.

Bull. Soc. Chim. Belge.
Bulletin de la Societe Chimique de Belgique. See previous journal.

Bull. Soc. Chim. France
Bulletin de la Societe Chimique de France, Paris.

California Derrick
California Derrick, San Francisco.

Calif. Jour. Tech.
California Journal of Technology, Berkeley.

Canad. Min. Inst., Trans., and Bull.
Canadian Mining Institute, Transactions, and Bulletin, Ottawa.

Canad. Min. Jour.
Canadian Mining Journal, Toronto.

Chem. Abst.
Chemical Abstracts, Easton, Pa.

Chem. & Met. Eng.
Chemical & Metallurgical Engineering, New York. Continuation, since 1918, of Metallurgical & Chemical Engineering.

Chem. Eng. & Min. Rev.
Chemical Engineering & Mining Review, Melbourne, Australia. Formerly the Mining & Engineering Review.

Chem. Trade Jour.
Chemical Trade Journal and Chemical Engineer, London.

Chem. Zeitg.
Chemiker-Zeitung, Coethen, Germany.

Comptes Rendus
Competes Rendus Hebdomadaires des Seances de l'Academie des Sciences, Paris.

Dingler's Polytech. Jour.
Dingler's Polytechnisches Journal, Stuttgart.

Durham Univ. Phil. Soc., Proc.
Durham University Philosophical Society, Proceedings, Newcastle-upon-Tyne, England.

Elect. Rev.
  Electrical Review, London.

Electrical Wld.
  Electrical World, N. Y.

Electrician
  Electrician, London.

L'Electricien
  L'Electricien, Paris.

Electrochem. Ind.
  Electrochemical Industry, New York. Continued since 1904 as Electrochemical and Metallurgical Industry, and since 1909 as Metallurgical and Chemical Engineering.

Electrochem. & Met. Ind.
  Electrochemical and Metallurgical Industry, New York. A continuation, since 1904, of Electrochemical Industry. Continued, since 1909, as Metallurgical and Chemical Engineering, and since 1918 as Chemical and Metallurgical Engineering.

Elektrochem. Zeits.
  Elektrochemische Zeitschrift, Berlin.

Engineering
  Engineering, London.

Eng. & Min. Jour., E. & M. J.
  Engineering & Mining Journal, New York.

Eng. Soc. West Pa., Proc.
  Engineers' Society of Western Pennsylvania, Proceedings, Pittsburg.

Faraday Soc., Trans.
  Faraday Society, Transactions, London.

Glueckauf
  Glueckauf, Essen, Germany.

Inst. Min. Eng., Trans.
  Institution of Mining Engineers, Transactions, Newcastle-upon-Tyne, England.

Inst. Min. & Met., Trans.
  Institution of Mining and Metallurgy, Transactions, London.

Iron Age
  Iron Age, New York.

Iron & Coal Trades Rev.
Iron & Coal Trades Review, London.

Iron Trade Review
Iron Trade Review, Cleveland.

Jour. Amer. Chem. Soc.
Journal of the American Chemical Society, Easton, Pa.

Jour. Chem. Met. & Min. Soc. So. Africa
Journal of the Chemical, Metallurgical and Mining Society of South Africa, Johannesburg.

Jour. Chem. Soc.
Journal of the Chemical Society, London.

Jour. de Pharm. Chim.
Journal de Pharmacie et de Chimie, Paris.

Jour. Franklin Inst.
Journal of the Franklin Institute, Philadelphia.

Jour. Ind. & Eng. Chem.
Journal of Industrial and Engineering Chemistry, Easton, Pa.

Jour. Phys. Chem.
Journal of Physical Chemistry, New York.

Jour. Russ. Phys. Chem. Soc.
Journal of the Russian Physico-Chemical Society, Petrograd.

Jour. Soc. Chem. Ind., J. S. C. I.
Journal of the Society of Chemical Industry, Manchester and London.

Jour. Wash. Acad. Sci.
Journal of the Washington Academy of Sciences, Baltimore.

Met. & Chem. Eng.
Metallurgical and Chemical Engineering, New York. Continuation, since 1909, of Electrochemical and Metallurgical Industry. Continued, since 1918, as Chemical and Metallurgical Engineering.

Metall u. Erz
Metall und Erz, Halle, Germany. Continuation, since 1912, of Metallurgie.

Metallurgie
Metallurgie, Halle, Germany. Continued, since 1912, in two parts. i. e., Metall und Erz, and Ferrum.

Metal Industry
Metal Industry, London.

Metaux et Alliages
Revue Scientifique, Industrielle et Commerciale des Metaux et Alliages, Paris.

Mex. Min. Jour.
Mexican Mining Journal, Mexico City. Each issue has both English and Spanish text.

Mineral Industry.
Mineral Industry, New York. (annual)

Mines & Minerals
Mines and Minerals, Scranton, Pa. Continued, since 1913, as The Colliery Engineer.

Min. & Met. Soc. of Amer. Bull.
Mining & Metallurgical Society of America, Bulletin, New York.

Min. & Eng. Rev.
Mining & Engineering Review, Melbourne, Australia. Continued as Chemical Engineering and Mining Review.

Min. & Sci. Press
Mining and Scientific Press, San Francisco.

Min. Jour.
Mining Journal, London.

Min. Mag.
Mining Magazine, London.

Min. Mag., N. Y.
Mining Magazine, New York.

Min. Sci.
Mining Science, Denver.

Min. Wld.
Mining World, Chicago. Absorbed, 1917, in Engineering & Mining Journal, New York.

Monats. f. Chem.
Monatshefte fuer Chemie, Vienna.

Moniteur Scient.
Moniteur Scientifique, Paris.

Oester Zeits. f. Berg- u. Huettenw.
Oesterreichische Zeitschrift fuer Berg- und Huettenwesen, Vienna.

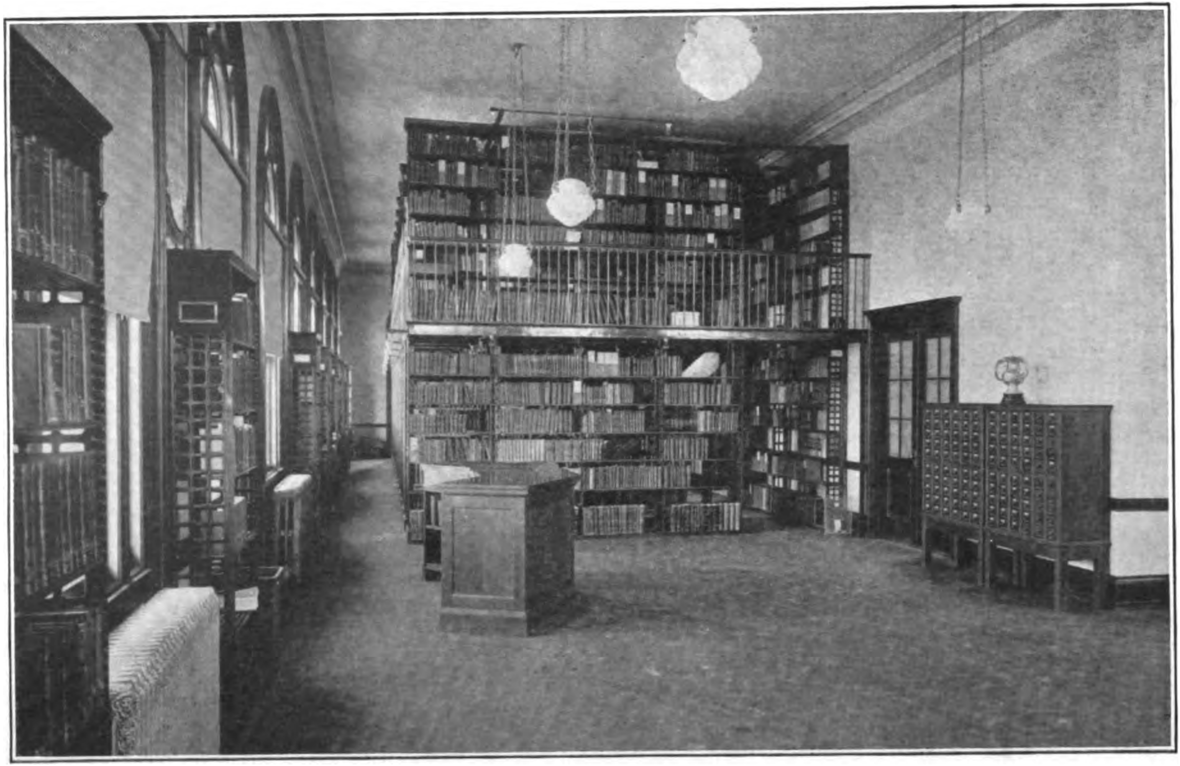
Revista Minera	Revista Minera, Madrid.
Rev. d'Electrochim. et d'Electromet.	Revue de l'Electrochimie et de l'Electrometallurgie, Paris.
Rev. Gen. de Chim.	Revue Generale de Chimie Pure et Appliquee, Paris.
Revue Industrielle	Revue Industrielle, Paris.
Rev. Univ. des Mines	Revue Universelle des Mines, de la Metallurgie, Paris.
Salt Lake Min. Rev.	Salt Lake Mining Review, Salt Lake City.
School of Mines Quart.	School of Mines Quarterly, Columbia University, New York.
Science	Science, New York.
Sci. Abst. A or B.	Science Abstracts A (Physics) or B (Electrical Engineering), London.
Sci. Amer. Suppl.	Scientific American Supplement, New York.
Soc. Ingen. Civils de France, Memoires	Societe des Ingenieurs Civils de France, Memoires, Paris.
Technology Quarterly	Technology Quarterly, Boston.
Tidskrift for Kemi, Farmaci og Terapi	Tidskrift for Kemi, Farmaci og Terapi, Christiania, Norway.
West. Chem, & Met.	Western Chemist and Metallurgist, Denver.
Zeits. des Oberschles. Berg- u. Huettenm. Vereins.	Zeitschrift des Oberschlesisches Berg- und Huettenmaennisches Vereins, Kattowitz, Silesia.
Zeits. f. anal. Chem.	Zeitschrift fuer analytische Chemie, Wiesbaden.
Zeits. f. angewandte Chem.	Zeitschrift fuer angewandte Chemie, Leipzig.

Zeits. f. anorgan. Chem.
Zeitschrift fuer anorganische Chemie, Leipzig.

Zeits. f. Elektrochem.
Zeitschrift fuer Elektrochemie und angewandte physikalische Chemie, Halle.

7th Int. Cong. Appl. Chem.
7th International Congress of Applied Chemistry, London, 1909. Proceedings.

8th Int. Cong. Appl. Chem.
8th International Congress of Applied Chemistry, New York and Washington, 1912. Original Communications.



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BIBLIOGRAPHY OF THE ROASTING, LEACHING, SMELTING AND ELECTROMETALLURGY OF ZINC

SOME REFERENCES ON THE GENERAL METALLURGY OF ZINC

Annual reviews of progress in the metallurgy of zinc may be found in the annual volumes of "The Mineral Industry" and of the U. S. Geological Survey's publication, "Mineral Resources of the United States," both of which usually include bibliographies; also in the early January numbers, each year, of various mining periodicals, especially in The Engineering and Mining Journal.

1 Cours de metallurgie des metaux autre que le fer.—**Eugene Prost.** Paris and Liege, Beranger, 1912. 888pp., diagr., 8°.

Metallurgy of the non-ferrous metals. The first 148 pages are devoted to the metallurgy of zinc, chiefly roasting and smelting.

2 Handbook of metallurgy.—**Carl Schnabel**; translated by Henry Louis. 2nd edition. London, Macmillan & Co., 1905-1907. 2 vols. illus., diagr., 8°.

The metallurgy of zinc is discussed in vol. 2, pp. 1-316. Contents: Zinc ores; Preparation of ores for reduction; Process of reduction; Belgian and Silesian methods; Older, direct-fired furnaces; Experiments and proposals for the improvement of the dry method; Extraction by combined wet and dry methods; Electrolytic extraction; Electrolytic extraction in the dry way.

1st German edition, 2 vols., Berlin, 1894-96; 1st English edition, 2 vols., London, 1898; 2nd German edition, 2 vols., Berlin, 1901-04; 2nd English, from the 2nd German edition, 2 vols., London, 1905-07; 3rd German edition, 2 vols., announced, 1915, as forthcoming shortly.

3 Metallurgie du zinc.—**A. Lodin.** Paris, Dunod, 1905. 810 pp., illus., diagr., 8°.

Calcination of calamines; Roasting of blendes; Reduction of zinc ores, with detailed description of various methods and types of furnaces; Electrolytic zinc; Zinc white.

4 The metallurgy of zinc and cadmium.—**Walter Renton Ingalls.** 2nd edition. N. Y., McGraw-Hill Book Co., 1906. 701pp., illus., diagr., 8°.

Zinc and its ores; Calcination of calamine; Blende roasting; Roasting furnaces; Utilization of the sulphurous gases; General principles of zinc distillation; Retort and condenser manufacture; Fuel and systems of combustion; Chimneys, heat recuperation and furnace design; Distillation furnaces; Practice in distillation; Losses in distillation; Refining impure zinc; Cadmium and its recovery; Cost of producing zinc; Design and construction of smelting works; Examples from practice; Proposals to smelt zinc ore in the blast furnace; Manufacture of zinc dust, zinc white, zinc sulphate and zinc chloride.

4a The zinc industry.—**Ernest A. Smith,** London, Longmans, Green & Co., 1918. 223 pp., illus., 8°. (Monographs on Industrial Chemistry.)

History of zinc; Rise and progress of the production of zinc; Zinc ores and their sources of supply; Marketing zinc ores; Zinc smelting; Other methods of zinc production; Physical and chemical properties of zinc; Industrial zinc alloys. Bibliography, pp. 213-221.

5 Zink und Cadmium, und ihre Gewinnung aus Erzen und Nebenprodukten.—**R. G. Max Liebig.** Leipzig, Otto Spamer, 1913. 598pp., illus., diagr., 8°.

Historical review; The Silesian, Belgian and Rhenish methods; Calcination of calamine; Roasting of blende; Reduction, distillation and condensation of zinc; Electric smelting; Electrolytic zinc.

6 The action on zinc of dilute sulphuric acid.—**F. Pullinger,** Jour. Chem. Soc., vol. 57, pp. 815-27. 1890.

The effect on zinc with smooth or rough surface, or sulphuric acid which has been boiled; influence of reducing agents.

—Abstract. Jour. Soc. Chem. Ind., vol. 9, pp. 946-47. Oct. 31, 1890.

7 The behaviour of certain alloys when heated in vacuo.—**Thomas Turner.** Jour. Inst. Metals, vol. 7, pp. 105-22. 1912.

"Zinc and other metals are entirely removed from copper-zinc alloys when the latter are heated in a vacuum."

—Abstract. Jour. Soc. Chem. Ind., vol. 31, p. 134. Feb. 15, 1912.

8 Comments and speculations on the metallurgy of zinc.—**W. R. Ingalls.** diagr. Eng. & Min. Jour., vol. 102, pp. 621-24. Oct. 7, 1916.

"A discussion of the details of zinc metallurgy and some of the improvements that may be realized." Electrolytic zinc; zinc burning; fume collecting; roasting and distillation furnaces; briquetting; retorts; pre-reduction.

—Abstract. Jour. Soc. Chem. Ind., vol. 35, p. 1159. Nov. 30, 1916.

9 Decomposition of zinc carbonate by alkali chlorides in the presence of water.—**A. Cantoni** and **J. Passamanik.** Ann. Chim. Anal., vol. 10, pp. 258-62. 1905. In French.

—Abstract. Jour. Soc. Chem. Ind., vol. 24, p. 925. Sept. 15, 1905.

10 The development of the spelter industry.—**Ernest A. Smith.** Jour. Inst. Metals, vol. 16, pp. 118-95. 1916.

American and European practice; treatment of complex ores; smelting, electric smelting and hydrometallurgical extraction; future of the zinc industry. Discussion by H. K. Picard, Robert Mond, W. Rosenhain, H. M. Ridge and others.

—Abstract. Min. Jour., vol. 114, pp. 647, 665-66, 680-83, 689-90, 699-700. Sept. 23, 30, Oct. 7, 14, 21, 1916.

—Abstract. Jour. Soc. Chem. Ind., vol. 35, pp. 996-99. Oct 16, 1916.

11 Fortschritte in der Metallurgie von Zink, Kupfer, Blei, Gold und Silber im Jahre 1913.—**K. Nugel.** illus. Metall u. Erz, vol. 11, pp. 226-42. Apr. 8, 1914.

Progress in 1913. Muffle process, treatment of residues, electrothermic methods.

—Abstract. Min. Wld., vol. 42, p. 459. Mar. 6, 1915.

12 Losses in zinc metallurgy. Eng. & Min. Jour., vol. 104, pp. 949-50. Dec. 1, 1917.

13 Losses of zinc in mining, milling and smelting.—**Dorsey A. Lyon** and **S. S. Arentz.** Amer. Inst. Min. Eng., Trans., vol. 49, pp. 789-801. 1914.

—Same. Amer. Inst. Min. Eng., Bull., July, 1914, pp. 1411-23.

—Abstract. Met. & Chem. Eng., vol. 12, p. 655. Oct., 1914.

14 The Metallurgy of zinc; discussion by **George C. Stone, W. R. Ingalls, W. McA. Johnson, E. Spilsbury.** Amer. Inst. Min. Eng., Bull., Jan., 1914, pp. 163-76.

Smelting, electric smelting, electrolytic zinc.

15 The occurrence of germanium in zinc materials.—**G. H. Buchanan.** Jour. Ind. & Eng. Chem., vol. 8, pp. 585-86. July, 1916.

—Abstract. Amer. Jour. Science, ser. 4, vol. 42, pp. 430-31. Nov., 1916.

16 Presidential address.—**H. L. Sulman.** Inst. Min. & Met., Trans., vol. 20, pp. xxxv-lxvi. 1911.

Problems of zinc metallurgy; flotation, roasting, leaching, smelting.

—Abstract. Modern zinc problems. Mex. Min. Jour. vol. 14, pp. 26-27. Jan., 1912.

17 The problem of mixed sulphide ore.—**W. R. Ingalls.** Canad. Min. Inst., Jour., vol. 14, pp. 479-86. 1911.

"A review of the attempts to treat impure zinc-sulphide ores, a summary of the basic conditions and the probable trend of experimentation."

—Same. Eng. & Min. Jour., vol. 92, pp. 211-13. July 29, 1911.

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19 Review of the zinc industry.—**Franz Meyer.** Electrochem. & Met. Ind., vol. 3, pp. 7-9. Jan., 1905.

Reviews a number of roasting, smelting and electrolytic processes.

—Same. Der technische Stand der Zink-industrie. Metallurgie, vol. 2, pp. 88-95. Feb. 22, 1905.

—Abstract. Zeits. f. angewandte Chem., vol. 18, pp. 901, 1327. June 23, Aug. 18, 1905.

20 Schmelzwaermen- und spezifische Waermebestimmungen von Metallen bei hoeheren Temperaturen.—**Ferdinand Glaser.** Metallurgie, vol. 1, pp. 103, 121-28. Mar. 22, April 8, 1904.

Determination of smelting and specific heat of metals at high temperatures. Lead, zinc, aluminum, copper, tin.

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24 Treatment of Franklinite.—**Titus Ulke.** Mineral Industry, vol. 2, pp. 673-74. 1893.

25 The treatment of zinc ores.—**A. S. Colclough-Nettell.** Canad. Min. Jour., vol. 35, pp. 94-96. Feb. 1, 1914.

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29 Zinc in Canada.—**Alfred Stansfield.** Canad. Min. Inst., Bull. 41, pp. 647-49. Sept., 1915.
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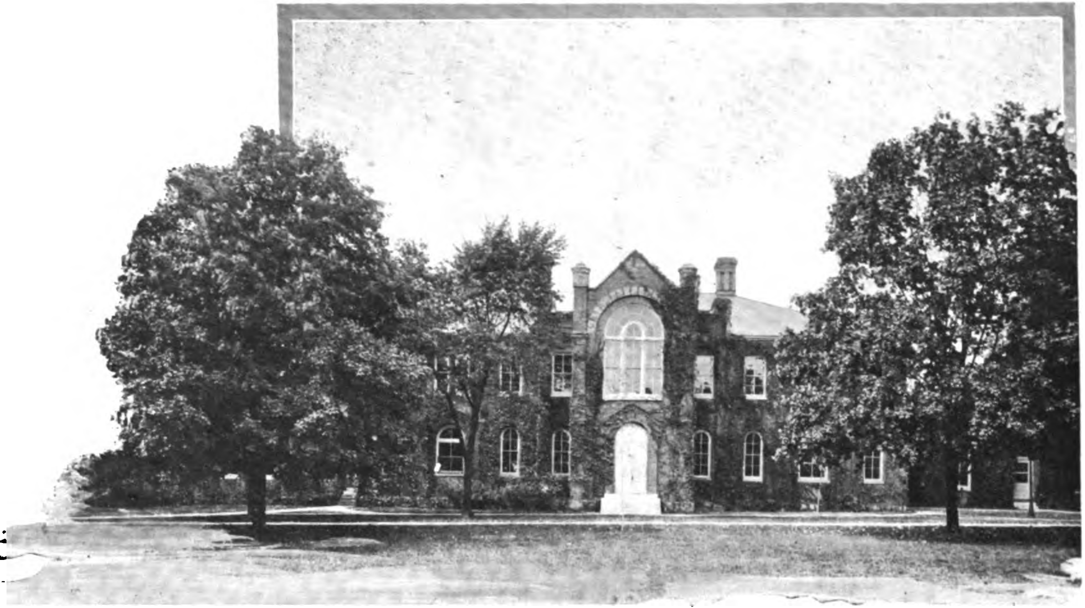

CHEMISTRY BUILDING

ANALYSIS, DETERMINATION, ESTIMATION

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Determination of zinc, using a cyanide electrolyte, using ammonium sulphate and ammonia as electrolyte, and using sodium hydroxide as electrolyte.

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37 Determination cuantitativa del zinc por electrolisis.—**Enrique Hauser.** Revista Minera, vol. 56, pp. 112-13. 1905.

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In opposition to Price, Porter and Frary, and others, the authors maintain that their method is accurate for zinc.

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40 The electrolytic deposition of zinc, using rotating electrodes.—**T. Slater Price** and **G. H. B. Judge.** diagr. Faraday Soc., Trans., vol. 2, pp. 85-90; vol. 3, pp. 88-97. Dec., 1906, July, 1907.

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Experiments showing that the zinc content of an ore can be accurately determined electrolytically, this method being shorter than the gravimetric.

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43 Electrolytic determination of zinc in presence of ammonium salts.—**R. Belasio.** Jour. Soc. Chem. Ind., vol. 31, p. 955. Oct. 15, 1912.

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Two methods are given: (1) double cyanide of zinc and potassium with great excess of soda; (2) sulphate of zinc with salts of organic acids and a slight excess of acetic acid. Abstracted from Bull. Soc. Chim. France, ser. 3, vol. 29, pp. 266-69.

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Paper before zinc symposium of American Chemical Society.

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Experiments using platinum electrodes, and zinc electrodes.

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Ferrocyanide methods

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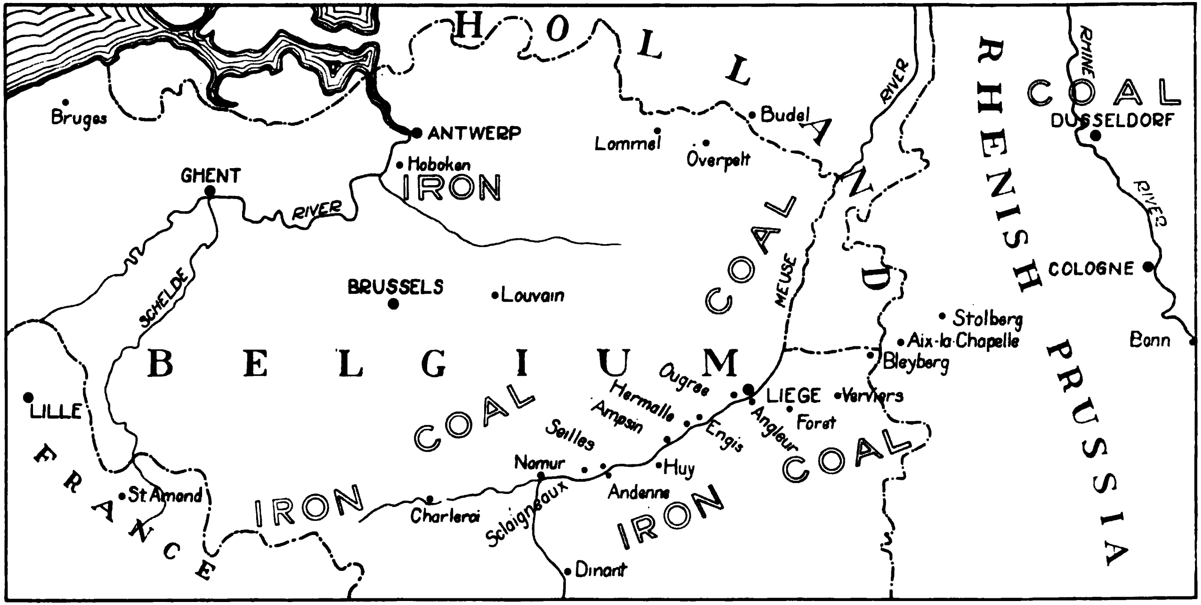

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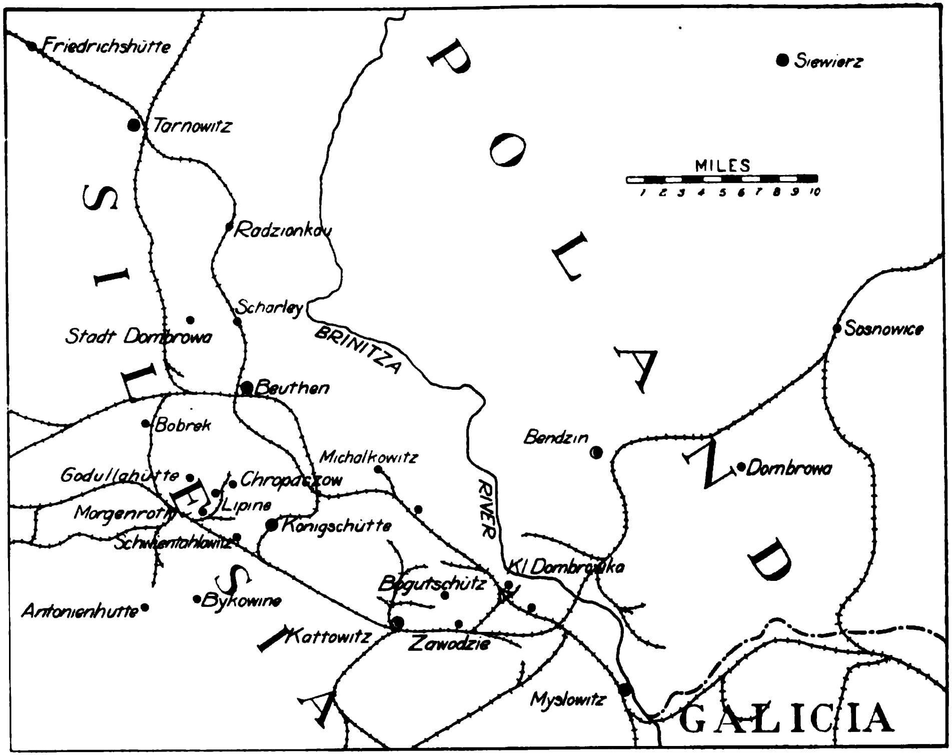
THE LEAD AND ZINC SMELTING CENTERS OF BELGIUM



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ROASTING

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Roasting Furnaces

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Wedge furnace

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247 Wedge roasting furnace with external fire-boxes. diagr. Eng. & Min. Jour., vol. 95, p. 506. Mar. 8, 1913.

U. S. Patent 1,040,071. Defects in most types of furnace are due to irregularity of heat; the Wedge furnace overcomes this difficulty by introducing heat chambers between successive treatment hearths.

248 Wedge roasting furnaces for lead matte and zinc ores. illus. Eng. & Min. Jour., vol. 102, pp. 625-26. Oct. 7, 1916.

249 Wedge zinc roaster. illus. Min. Wld., vol. 46, p. 52. Jan. 6, 1917.

Zellweger furnace

250 Recuperative zinc ore roaster. diagr. Met. & Chem. Eng., vol. 10, p. 307. May, 1912.

U. S. Patent 1,017,839.

251 Zellweger kilns, at Deering plant of American Zinc, Lead and Smelting Company.—**Evans W. Buskett.** illus. Eng. & Min. Jour., vol. 90, pp. 502-3. Sept. 10, 1910.

Ore mechanically handled; kilns reduce sulphur from 30% to 1%. Furnaces are four tiers high, and contain 320 retorts.

252 The Zellweger roasting kiln. illus., diagr. Eng. & Min. Jour., vol. 69, pp. 260-62. Mar. 3, 1900.

Kiln of the Cherokee Lanyon Spelter Co., at Gas City, Kas. "The main feature of this machine roaster is the rolling stirrer."

Calcining

253 The calcination of zinc carbonate.—**William P. Simpson.** Met. & Chem. Eng., vol. 14, pp. 181-83. Feb. 15, 1916.

254 The Cermak-Spirek furnace.—**A. A. Francis.** Eng. & Min. Jour., vol. 76, p. 541. Oct. 10, 1903.

Performance of furnace installed at Ponte di Nossa by the English Crown Spelter Co., Ltd., in 1901, for the calcination of calamine.

255 The Cermak-Spirek furnace for calcining and roasting zinc ores.—**Vincent Spirek.** diagr. Mineral Industry, vol. 10, pp. 684-87. 1901.

Chloridizing roasting

256 Chloridizing blast roasting and leaching.—**G. A. Keep.** illus., diagr. Eng. & Min. Jour., vol. 99, pp. 265-69, 315-22. Feb. 6, 13, 1915.

257 The chloridizing roasting of ores. Met. & Chem. Eng., vol. 12, p. 140. Feb., 1914.

U. S. Patent 1,082,599, by August D. Ledoux.

258 Verarbeitung zinkhaltiger Kiesabbraende durch chlorirende Roestung.—**W. Stahl.** Berg- u. Huetten. Zeitg., vol. 33, pp. 1-4. Jan. 5, 1894.

Oxidizing roasting

259 Desulphurizing zinc sulphate. Eng. & Min. Jour., vol. 93, p. 1180. June 15, 1912.

French Patent 432,556, by Hermann Pape, Oker-in-the Harz, Germany. The sulphur is heated in an intimate mixture with zinc oxide, expelling the sulphur as sulphurous acid.

260 Die Entwicklung der Zinkblenderoestung.—**E. Schuetz.** illus. Metallurgie, vol. 8 pp. 635-45. Oct. 22, 1911.

"Historical review of the development of the methods of blende roasting, with descriptions of some of the furnaces employed in Europe and America."

—"Bemerkungen." Metallurgie, vol. 8, pp. 713-14. Nov. 22, 1911.

—Abstract. Zeits. f. angewandte Chem., vol. 25, pp. 496-97. Mar. 8, 1912.

—Translation, by O. H. Hahn: Practice in blende roasting. diagr. Eng. & Min. Jour., vol. 93, pp. 557-60. Mar. 16, 1912.

261 Improved roasting process. diagr. Met. & Chem. Eng., vol. 9, p. 156. Mar., 1911.

Renwick's Patent 981,880.

262 Labour problems in zinc smelting.—**W. Dewar.** Min. Mag., vol. 14, pp. 215-16. Apr., 1916.

Correspondence in regard to item 722. "Introduction of mechanical means does not necessarily imply the best solution of a difficulty." Compares De Place and Hegeler roasting furnaces.

263 Oxydierende Roestung sulfidischer Zinkerze in sauerstoff- und wasserdampfhaltigen Verbrennungsgasen. Metallurgie, vol. 9, pp. 460-61. July 22, 1912.

Oxidizing roasting of blende in oxygen and steam bearing combustion gases. German patent by Borchers and others.

264 Preparation of zinc oxide for reduction. Eng. & Min. Jour., vol. 89, p. 874. April 23, 1910.

U. S. Patent 947,399, by Hermann Pape. A muffle furnace condenses the oxide into lumps.

265 Roasting and leaching tailings at Anaconda.—**Frederick Laist.** diagr. Min. & Eng. Wld., vol. 39, pp. 545-48, 599-601. Sept. 27, Oct. 4, 1913.

Use of oxidizing roast on mill tailings. Tables and diagrams. Applies chiefly to copper.

266 Roasting for wet process. Electrochem. & Met. Ind., vol. 5, p. 33. Jan., 1907.

Angell's Patent 837,273. "The object is to produce soluble sulphates direct from zinciferous ores which are sulphide blende."

267 The roasting of blendes.—**M. V. M. de Lummen.** Chem. Trade Jour., vol. 59, pp. 261-62. 1916.

"A study of three systems applicable to the roasting of Australian concentrates, i. e., the Hegeler, Spirlet, and Delplace. Data of operation and comparative costs are given," based on prices ruling before the war. See also item 202.

—Same. Eng. & Min. Jour., vol. 102, pp. 741-42. Oct. 21, 1916.

—Abstract. Jour. Soc. Chem. Ind., vol. 35, p. 1064. Oct. 31, 1916.

—Abstract. Chem. Abst., vol. 10, p. 3053. Dec. 10, 1916.

268 Roasting of sphalerite.—**Joseph W. Richards.** Electrochem. & Met. Ind., vol. 6, pp. 141-43. April, 1908.

Published later in his book "Metallurgical calculations," pt. 3. N. Y., McGraw-Hill Book Co., 1908.

269 Roasting of zinc ore for retort smelting. Met. & Chem. Eng., vol. 15, p. 158. Aug. 1, 1916.

De Saulles' U. S. Patent 1,183,172. Adds carbon in the form of anthracite coal to the roasting ore, with the effect that undesirable constituents are broken up at the higher temperature produced."

270 Roasting zinc flotation concentrates. Met. & Chem. Eng., vol. 14, p. 103. Jan., 1916.

L. C. Drefahl's Patent 1,153,203. Mixes the fine concentrates with moisture to make a plastic mass.

271 Roasting zinc blende.—**W. Minor.** Chem. Zeitg., vol 13, pp. 1602-3. 1889.

The time required for the elimination of sulphur from different varieties of blende varies from two to six hours. To determine the cause of this variation, the author carefully selected samples and analyzed them at intervals. In German.

—Abstract. Jour. Soc. Chem. Ind., vol. 9, p. 76. Jan. 31, 1890.

272 Roestoefen fuer Blende und Pyrite.—**W. R. Ingalls.** diagr. Metallurgie, vol. 1, p. 449-56. Nov. 8, 1904.

American roasting practice, with descriptions of McDougall, Herreshoff, Klepetko and other furnaces.

—Abstract. Zeits. f. angewandte Chem., vol. 18, p. 343. Mar. 3, 1905.

273 Some practical notes on ore roasting.—**J. E. Edwards.** Min. Wld., vol. 32, pp. 553-55. Mar. 12, 1910.

274 Studien ueber Abroestung von Zinksulfidniederschlaegen und ueber ein neues Mittel zur schnellen Ausflockung dieser Niederschlaege aus saurer Loesung. (Gegenseitige Faellung zweier Kolloide, angewandte auf ein analytisches Problem.)—**K. Bornemann.** Zeits. f. anorg. Chem., vol. 82, pp. 216-39. July 8, 1913.

The roasting of zinc sulphide precipitates and a method for their rapid separation in an acid solution. Precipitates of zinc sulphide may be accurately roasted direct to oxide.

—Abstract: Zinc sulphide precipitates. Jour. Inst. Metals, vol. 10, pp. 438-39. 1913.

275 Sulphur in roasting.—**William E. Greenawalt.** Eng. & Min. Jour., vol. 80, pp. 1164-65. Dec. 23, 1905.

—Correction. vol. 81, p. 238. Feb. 3, 1906.

276 Ueber die Bleiverfluechtigungen beim Roesten bleihaltiger Zinkblenden.—**Karl Sander.** Berg- u. Huettenm. Zeitg., vol. 61, pp. 561-62. Nov. 7, 1902.

277 Ueber sulfatisierende Roestung der sulfidischen Erze.—**Rudolf Vondracek.** Oester. Zeits. f. Berg- u. Huettenw., vol. 54, pp. 437-41, and vol. 55, pp. 95-96. 1906-07.

278 The utilization of the sulphur contents of zinc ore.—**H. M. Ridge.** diagr. Jour. Soc. Chem. Ind., vol. 36, pp. 676-85. July 16, 1917.

Discusses the extraction of the sulphur and its utilization; describes the Hasenclever, Rhenania, Delplace, Hegeler, Merton, Spirlet and Ridge furnaces.

—Same. diagr. Met. & Chem. Eng., vol. 17, pp. 215-24. Sept. 1, 1917.

—Same. diagr. Austral. Min. Stand., vol. 58, pp. 260-62. Oct. 25, 1917.

—Abstract. Min. Mag., vol. 17, pp. 41-42. July, 1917.

—Abstract. Chem. Abst., vol. 11, p. 3096. Nov 20, 1917.

279 Verarbeitung gemischter sulfidischer Zinkerze mit Ferrisulfat unter Oxydation des entstehenden Ferrosulfats und unter Nutzbarmachung der beim Kalzinieren von Zinksul erzeugten sauren Gase fuer den Arbeitsgang. Metallurgie, vol. 5, pp. 588-89. Oct. 8, 908.

Working up mixed sulphide zinc ores with ferric sulphate, oxidizing the resulting ferrous sulphates, and utilizing the acid gases by calcination of the zinc sulphate. De Bechi and Ruecker's German Patent 200,613.

280 Verfahren und Vorrichtung zum Roesten von Zinkblende, bei denen das Roestgut in eine drehbare Roestkammer eingefuehrt wird, in der eine oxydierende Roestatmosphaere aufrecht erhalten wird, waehren sich die Charge in Bewegung befindet. diagr. Metall u. Erz., vol. 12, pp. 510-11. Dec. 22, 1915.

Process and apparatus for roasting zinc blende, the roast being placed in a rotating chamber in which an oxidizing atmosphere is maintained, and the charge is kept in motion. German Patent 288,648, by A. L. J. Queneau. See item 397.

281 The zinc industry in Silesia in 1905.—**Paul Speier.** Eng. & Min. Jour., vol. 81, p. 176. Jan. 27, 1906.

Roasting for magnetic separation

282 Electric furnace conversion of iron pyrites into a magnetic form.—**O. L. Kowalke.** diagr. Amer. Electrochem. Soc., Trans., vol. 13, pp. 133-42. 1908.

In preparing mixed sulphide zinc ores for smelting, the removal of iron pyrites is often accomplished by roasting, so as to convert the iron magnetic sulphide to a metallic form. This investigation was to determine the temperature and conditions under which iron pyrites can be made magnetic.

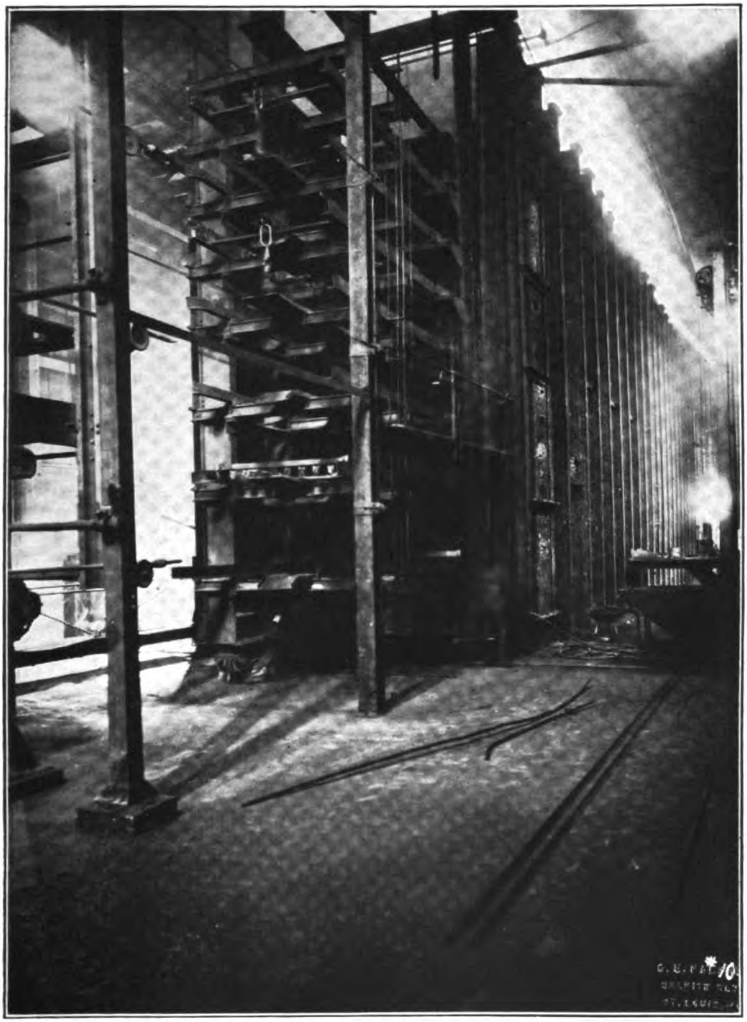
—Abstract in German. Metallurgie, vol. 5, pp. 539-40. Sept. 22, 1908.

283 The new Wilfley roaster. Eng. & Min. Jour., vol. 91, p. 622. Mar. 25, 1911.

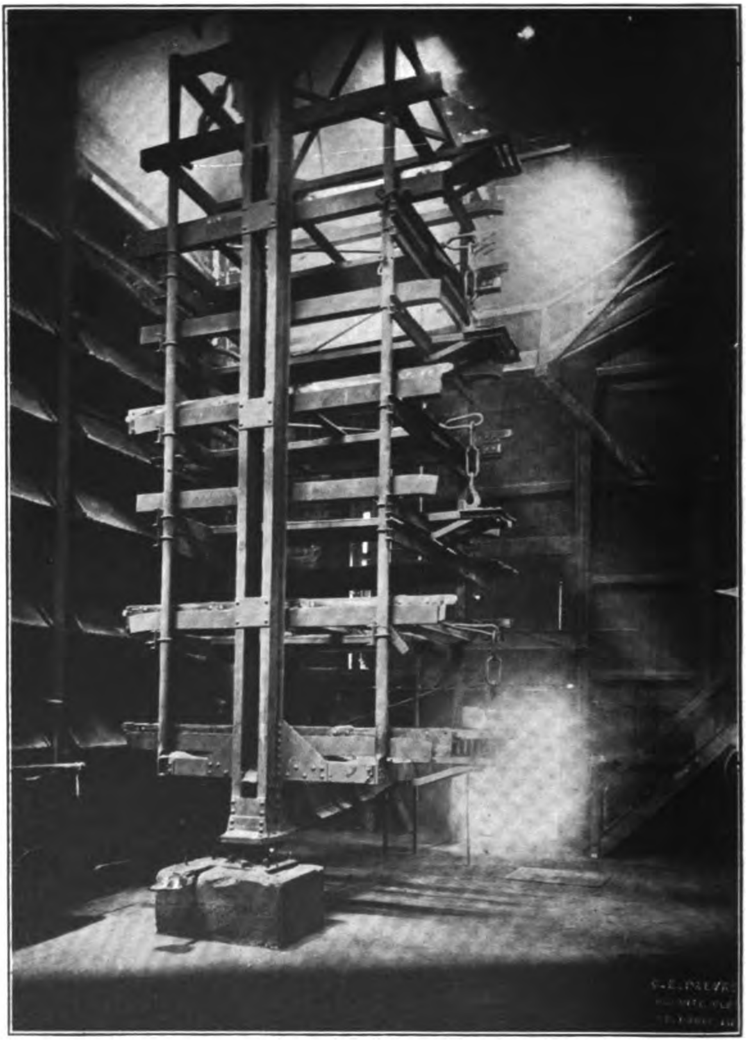
284 The removal of iron from zinc blende.—**William B. Phillips.** Eng. & Min. Jour., vol. 72, pp. 710-11. Nov. 30, 1901.

—Correspondence.—**Gilbert Rigg.** vol. 72, p. 857. Dec. 28, 1901.

—Abstract. Jour. Soc. Chem. Ind., vol. 21, pp. 120-21. Jan. 31, 1902.



HEGELER ROASTING FURNACE,
AMERICAN ZINC, LEAD & SMELTING CO.



HEGELER ROASTING FURNACE, END VIEW
AMERICAN ZINC, LEAD AND SMELTING CO.

285 Roasting and magnetic separation of a blende marcasite concentrate.—**H. O. Hofman** and **H. L. Norton.** illus. Amer. Inst. Min. Eng., Trans., vol. 35, pp. 928-47. 1905.

Marcasite and blende "can be successfully separated by crushing through a 20-mesh screen, roasting from 5 to 10 minutes at a temperature not exceeding 400° C., and then subjecting to two double-pole magnets."

—Same. Technology Quarterly, vol. 18, pp. 86-104. Mar. 1905.

—Abstract. Zeits. f. angewandte Chem., vol. 19, pp. 36-37. Jan. 5, 1905.

286 Roasting for magnetic separation of zinc ores.—**Frank H. Trego.** diagr. Eng. & Min. Jour., vol. 83, pp. 613-16. Mar. 30, 1907.

"A comparison of the work of the cylindrical furnace commonly used in southwestern Wisconsin with that of a new circular table roaster."—E. & M. J.

—Correspondence.—**C. C. Mathey.** Eng. & Min. Jour., vol. 83, p. 1060. June 1, 1907.

—Reply.—**F. A. Trego.** p. 1205. June 22, 1907.

287 Wilfley roasting process.—**J. M. McCave.** diagr. Mines & Minerals, vol. 28, p. 407. April, 1908.

288 The Wilfley rotary-hearth roaster. Eng. & Min. Jour., vol. 99, pp. 414-15. Feb. 27, 1915.

PATENTS ON ROASTING

United States

289 495,593. Process of manufacturing zinc oxide.—**George T. Lewis,** Philadelphia, Pa. Filed Sept. 28, 1891. Issued April 18, 1893.

The process of manufacturing zinc oxide from zinc ores containing sulphur, which consists in mixing with the ore sodium nitrate or its equivalent in quantity sufficient to unite with the sulphur present, roasting the mixture to effect the formation of a soluble sulphate, leaching out the soluble sulphate and finally oxidizing the zinc in the ores thus freed from sulphur and collecting the zinc oxide fume.

290 523,650. Roasting furnace.—**John Roger,** Denver, Colo. Filed May 29, 1893. Issued June 24, 1894.

291 566,750. Roasting furnace.—**John B. F. Herreshoff,** Brooklyn, assignor to the Nichols Chemical Company, New York. Filed March 29, 1895. Issued March 24, 1896.

292 569,901. Roasting furnace.—**James L. Wells,** Leadville, Colo. Filed Nov. 29, 1895. Issued October 20, 1896.

293 579,536. Roasting furnace.—**Jared E. Gaylord, William G. Cole,** and **Hermann A. Keller,** Butte, Mont. Filed March 10, 1894. Issued March 23, 1897. 23 claims.

294 579,711. Roasting furnace.—**Hermann A. Keller, William G. Cole,** and **Jared E. Gaylord,** Butte, Mont. Filed April 9, 1894. Issued March 30, 1897. 17 claims.

295 616,926. Roasting furnace.—**John B. F. Herreshoff,** New York. Filed Dec. 28, 1897. Issued January 3, 1899.

296 623,833. Roasting and smelting furnace.—**James A. Russell,** Tacoma, Wash. Filed July 30, 1898. Issued April 25, 1899.

297 624,048. Roasting furnace.—**Hermann A. Keller,** Butte, Mont. Filed Feb. 19, 1896. Issued May 2, 1899.

298 629,023. Roasting furnace.—**Lewis T. Wright,** Keswick, Cal. Filed November 24, 1897. Issued July 18, 1899.

299 641,460. Furnace for roasting and reducing ores.—**Harrison B. Meech,** Denver, Col. Filed Mar. 4, 1899. Issued Jan. 16, 1900.

In a cylindrical roasting-furnace, two or more ovens one above the other, each having an opening in the bottom or bed thereof, and a rotary, flanged, discharge-wheel located in each of said openings; in combination with a hollow vertical shaft in sections, joined together by center pieces having horizontal arms fast thereto, said center pieces and arms each interiorly divided into two chambers by a horizontal partition therein, and mechanism for rotating said shaft, in combination with a pawl-and-ratchet mechanism connected to said discharge-wheel and actuated by said arms.

300 642,334. Ore roasting and desulphurizing furnace.—**Albert C. Johnson,** Baltimore, Md. Filed Apr. 29, 1898. Issued Jan. 30, 1900.

In an ore roasting or desulphurizing furnace, longitudinal side beams having intersecting longitudinally-extending lateral and vertical slots, in combination with a reciprocating rake, the latter comprising a head with right-angled ends, and with teeth which are triangular in cross-section and arranged in staggered form, said rake pivoted to the head, endless chains or cables connected with the angular ends of the rake-head, and supported in the slot or pocket and on idlers exterior to the heating-chambers, and means for reciprocating the chain or cable. 5 claims.

301 645,761. Apparatus for oxidizing or roasting refractory ores.—**Robert A. Stewart,** Kansas City, Mo. Filed Dec. 15, 1899. Isued Mach 20, 1900.

An apparatus comprising a rotary ore-retaining cylinder, having a neck-passage, and an exit-opening of smaller diameter than said neck-passage, a furnace communicating with said neck-passage, a steam-pipe for discharging steam through the furnace and said neck-passage into said cylinder, and means for discharging steam and air into said neck-passage at an angle to the first named steam-pipe.

302 648,183 Roasting furnace.—**Utley Wedge,** Bayonne, N. J. Filed Sept. 29, 1898. Issued April 24, 1900.

In a roasting-furnace the combination with the roasting-chamber of a central shaft extending vertically through the roasting-chamber and having in said chamber arms provided with stirring-blades, a rim secured to said shaft beneath said chamber, wheels or rollers supporting said rim, and means for continuously rotating said shaft. 16 claims.

303 653,202. Ore roasting furnace.—**Philip Argall,** Denver. Filed Sept. 28, 1899. Issued July 10, 1900. 13 claims.

An ore roasting furnace provided with a reciprocating bottom, longer than the said furnace, and means for moving said bottom back and forth a specific distance equal to said excess of length, whereby the furnace always remains closed at the bottom.

304 654,335. Roasting furnace.—**Utley Wedge,** Ardmore, Pa. Filed Mar. 13, 1899. Issued July 24, 1900.

The combination of a tier of roasting chambers, furnace chambers interposed in the series of roasting chambers and not communicating therewith, but so communicating with each other that the combustion products of one furnace chamber are conducted into another, passages connecting the roasting chambers, with each other, whereby the material in the roasting chambers may be passed from chamber to chamber out of contact with any gases other than those generated therein, and stirring mechanism in each roasting chamber.

305 676,417 and 676,418. Apparatus for and method of roasting ores.—**Henry Carmichael,** Malden, Mass., assignor to the Carmichael Reduction Company, Portland, Me. Filed Jan. 24, 1901. Issued June 18, 1901.

The method of roasting refractory oxidizable ores, which consists in passing the ore forward through a combustion zone, oxidizing the combustible ingredients of said ore as completely as possible within said zone by the action of air, substantially wholly by the oxidation of the ore therein, and substantially retaining the heat produced by said oxidation; then passing the nearly oxidized ore through a second zone and simultaneously subjecting it in a disseminated condition to extraneous heat and to the action of air uncontaminated by products of combustion, whereby further oxidation of the ore is effected and practically all of the sulphur and arsenic are removed, and a dead roast obtained; positively disseminating the ore on its passage through said second zone, and supplying the requisite air by moving a current of air in contact with the ore and through the disseminated portion thereof but in the opposite direction to the line of feed of the ore.

306 677,263. Process of roasting mixed sulphide ores.—**Ernest C. H. Pape** and **Carl A. L. W. Witter,** Hamburg, Germany. Filed July 18, 1899. Issued, June 25, 1901.

The process of treating sulphide ores containing metals which are volatile at a temperature at which they cannot combine with oxygen, which consists in heating in a combustion chamber to a temperature necesary to ignite the sulphides in the ore, introducing a heated current of air in the said chamber, then feeding the finely divided ore into the chamber so that it passes through the current of heated air, maintaining the temperature above that at which a part of the metals can combine with oxygen, allowing the metallic vapors carried forward to combine with oxygen, and then collecting the matters so carried forward.

307 677,510. Roasting-Furnace.—**Benjamin Hall,** Nevada City, Cal. Filed Jan. 18, 1901. Issued July 2, 1901. 9 claims.

308 677,701. Ore-roasting Furnace.—**John Roger,** Denver, Col. Filed Feb. 12, 1901. Issued July 2, 1901. 3 claims.

309 678,078. Apparatus for desulphurizing ores or other substances.—**John P. Wetherill,** South Bethlehem, Pa. Filed November 6, 1897. Issued July 9, 1901.

The method of roasting by furnace heat a progressively moving or advancing charge of ore containing sulphur, which consists in excluding therefrom the products of combustion of the heating-furnace, admitting air at an initial portion of the ore and partially oxidizing the sulphur thereby, maintaining the roasting temperature along an advanced portion of the charge by the combustion of the sulphur, withdrawing the sulphur fumes at said advanced portion so as to prevent them from passing on over the remainder of the ore, and finally admitting additional quantities of air to oxidize the sulphur in portions of the charge still further advanced. 11 claims.

310 685,903. Roasting-furnace.—**John A. Bentley,** Denver, Col. Filed Feb. 19, 1900. Issued Nov. 5, 1901. 6 claims.

311 691,112. Ore roasting furnace.—**Joseph P. Cappeau,** Joplin, Mo. Filed Apr. 20, 1901. Issued Jan. 14, 1902.

312 692,008. Separating process for ores.—**Oscar Frol'ch,** Charlottenburg, **Max Huth,** Halensee, and **Arthur Edelmann,** Charlottenburg, Germany, assignors to Siemens & Halske Aktiengesellschaft, Berlin, Germany. Issued Jan. 28, 1902.

The process consists in heating the ore to a temperature below the decomposition temperature of the sulphate of the metals to be sulphated, but above the decomposing temperature of the sulphate of any other metal existing in the ore and then passing it over a gas mixture containing sulphur dioxide and oxygen.

313 691,148. Process of treating ores.—**Elizabeth B. Parnell,** Carshalton, England. Issued Feb. 11, 1892.

In the treatment of refractory ores, a process which consists in subjecting them to the action of chromic acid and then roasting them.

314 700,339. Roasting furnace.—**Frank Klepetko** and **William J. Evans,** Great Falls, Mont. Issued May 20, 1902.

In a furnace of the class described, a hearth, a roof therefor, a hopper thereabove having a constricted opening, means for agitating the material to be treated in the opening of said hopper consisting of rotary stirring arms projected from the upper outer edge of said hopper to the discharge opening thereof, and separate means for feeding the material from said hopper to said hearth.

.315 705,904. Desulphurizing of sulphide ores preparatory to smelting.—**Archibald D. Carmichael,** Broken Hill, New South Wales, Australia. Issued July 29, 1902.

A process of treating mixed sulphide ores, which consists in mixing with said ores a sulphur compound of a metal of the alkaline earths, starting the reaction by heating the same, thereby oxidizing the sulphide and reducing the sulphur compound of the alkali metal, passing a current of air to oxidize the reduced sulphur compounds of the metal of the alkalies preparatory to acting upon a new charge of sulphide ores.

316 709,482. Process of eliminating the sulphur from sulphide ores.—**Adolph Gutensohn,** London, England, assignor to Sulphur Elimination Syndicate, Ltd., London. Issued Sept. 23, 1902.

A process for the elimination of sulphur from sulphide ores, consisting in crushing the ore, mixing it with carbon and a sodium salt which will yield sulphide of sodium when the mixture is heated, the amount of carbon being added largely in excess of the amount required to form the sulphide of sodium, heating the mixture to a temperature approaching incipient redness and then exposing it freely to air to effect its oxidation and burn off all the sulphur that is set free.

317 736,929. Roasting furnace.—**Edward C. Brice,** Colwyn, Pa. Filed October 7, 1902. Issued August 23, 1903.

318 737,060. Art of treating ores for recovery of zinc and copper.—**Aron M. M. Beam,** Denver, Colorado. Filed May 12, 1899. Issued August 23, 1903.

The process of recovering zinc or copper from ores, consisting in first pulverizing the ore, then subjecting it, in connection with a suitable oxidizing flux or reagent mixed therewith, in a closed oven or muffle, to the action of a low degree of indirect heat while the air is excluded, for a short time, or until the sulphides of zinc or copper are partially converted into sulphates, so that the air may be afterward admitted without burning the sulphur, then admitting air to the ore in the oven or muffle, and completing the conversion of the sulphides into sulphates by subjecting the ore for a further short time to a low degree of indirect heat, then leaching the converted ore with water and finally precipitating.

319 756,485. Roasting or desulphurizing furnace.—**Frederick J. Falding,** New York, N. Y. Filed June 14, 1901. Issued April 5, 1904. 8 claims.

320 760,941. Ore-treating furnace.—**Christopher C. Wilson,** Denver, Colorado. Filed Aug. 18, 1903. Issued May 24, 1904.

321 761,049. Ore-roasting furnace.—**William H. Smyth,** Berkeley, Cal. Filed March 12, 1901. Issued May 24, 1904. 40 claims.

321a 761,050. Ore-roasting furnace.—**William H. Smyth,** Berkeley, Cal. Filed March 12, 1901. Issued May 24, 1904. 10 claims.

322 768,748. Roasting furnace.—**Ottokar Hofmann,** Argentine, Kansas. Assignor to the United Zinc and Chemical Company, Kansas City, Mo. Filed August 29, 1903. Issued August 30, 1904. 8 claims.

323 775,147. Ore-roasting furnace.—**Andrew P. O'Brien,** Richmond, Va. Filed April 3, 1903. Issued September 15, 1904. 26 claims.

324 779,310. Process of obtaining metals from their ores—**Samuel Peacock,** Chicago, Ill. Filed Feb. 17, 1904. Issued January 3, 1905.

The process of treating ores containing iron and zinc which consists in roasting the same, reducing the iron to a metallic state at a temperature too low to reduce the zinc to a metallic state, separating the iron from the mass and then reducing the zinc to a metallic state.

325 779,717. Roasting furnace.—**Frank Klepetko,** New York, N. Y. Filed Oct. 3, 1904. Issued January 10, 1905.

In a furnace having a plurality of hearths, a rotable hollow shaft passing through the hearths, a series of hollow arms radiating from said shaft and extending into the several hearths, a series of chambers distributed throughout the shaft and communicating with the hollows arms, means for permitting the circulation therethrough of a current of air, and a series of deflecting-ribs disposed along the inner surfaces of the hollow arms. 10 claims.

326 780,115. Roasting furnace.—**August R. Meyer,** Kansas City, Mo., assignor to the United Zinc and Chemical Company, Kansas City, Mo. Filed March 17, 1904. Issued January 17, 1905. 19 claims.

327 781,824. Rotary ore roasting furnace.—**Ferdinand Heberlein,** London, and **Woldemar Hommel,** Lee, England. Filed June 11, 1904. Issued Feb. 7, 1905.

A rotary muffle-furnace for roasting ores or the like, comprising an ore-chamber the floor of which rotates, a heating chamber immediately beneath, rotating with the floor of the ore-chamber, and a stationary heating-chamber immediately above the ore-chamber; the heating gases being caused to circulate first through the lower heating chamber and subsequently through the upper one.

328 785,437. Roasting furnace.—**Charles Repath** and **Frank E. Marcy,** New York, N. Y., assignors to Frank Klepetko, New York, N. Y. Filed May 9, 1904. Issued March 21, 1905.

In a furnace having a plurality of superposed hearths, means for conducting the material from one hearth to the next hearth below in such a manner that there is always an uninterrupted body of material connecting the material on one hearth with that on the next adjacent hearth.

329 786,567. Roasting furnace.—**Walter R. Ingalls,** Lynn, Mass. Filed Feb. 15, 1904. Issued April 4, 1905.

330 786,599. Roasting furnace.—**Charles H. Repath** and **Frank E. Marcy,** New York, N. Y., assignors to Frank Klepetko, New York, N. Y. Filed May 25, 1904. Issued April 4, 1905.

331 792,053. Roasting furnace.—**Frank Klepetko,** New York. Filed Dec. 31, 1904. Issued June 13, 1905. 9 claims.

332 793,939. Roasting furnace.—**Frank E. Klepetko,** New York, N. Y. Filed Oct. 22, 1904. Issued July 4, 1905.

333 794,198. Process of removing or recovering zinc from ores. **William Stewart,** Mount Florida, Glasgow, Scotland. Filed June 28, 1904. Issued July 11, 1905.

A process for removing or recovering zinc from ores containing it, said process consisting of pulverizing the ores, mixing therewith bisulphate of an alkali metal, and common salt, furnacing at a red heat and thereafter lixiviating or leaching and precipitating tne zinc salts.

334 794,837. Roasting furnace.—**Joseph A. Anker, James H. Watson,** and **Pierce Evans,** Los Angeles, Cal.; said Anker and Evans assignors to said Watson. Filed Dec. 10, 1903. Issued July 18, 1905. 9 claims.

335 799,063. Roasting furnace.—**Frank Klepetko,** New York, N Y. Filed Mar. 15, 1905. Issued Sep. 12, 1905. 8 claims.

336 799,743 Process of treating zinc ores.—**Philip A. Mackay,** Wenona, Ill. Filed June 9, 1902. Issued Sept. 19 1905.

The process of treating zinc ores containing cadmium sulphide and zinc sulphide, which consists in subjecting ore to a dead roast, whereby the zinc sulphide is oxidized and the cadmium sulphide converted into cadmium sulphate, thereafter dissolving out this deleterious sulphate and then grinding and distilling the remaining zinc oxide to obtain therefrom the pure refined zinc.

337 799,745. Metallurgical furnace.—**Philip A. Mackay,** Newcastle, New South Wales, Australia. Filed Apr. 29, 1903. Issued Sept. 19, 1905.

338 800,588. Roasting furnace.—**August R. Meyer**, Kansas City, Mo., assignor to the United Zinc and Chemical Co., Kansas City, Mo. Filed Oct. 12, 1903. Issued Sept. 26, 1905.

339 804,751. Roasting furnace.—**August R. Meyer**, Kansas City, Mo., assignor to the United Zinc and Chemical Co., Kansas City, Mo. Filed Mar. 17, 1904. Issued Nov. 14, 1905.

340 804,752. Roasting furnace.—**August R. Meyer**, Kansas City, Mo., assignor to the United Zinc and Chemical Co., Kansas City, Mo. Filed Mar. 17, 1904. Issued Nov. 14, 1905.

341 809,953. Roasting furnace.—**Ottokar Hofmann**, Argentine, Kans., assignor to the United Zinc and Chemical Co., Kansas City, Mo., a Corporation of New Jersey. Filed Feb. 19, 1904. Issued Jan. 16, 1906. 8 claims.

342 811,643 Roasting furnace.—**Frank Klepetko**, New York, N. Y. Filed Nov. 6, 1905. Issued Feb. 6, 1906. 12 claims.

343 814,297. Roasting furnace.—**Frank Klepetko**, New York, N. Y. Filed Nov. 6, 1905. Issued Mar. 6, 1906. 8 claims.

344 814,298. Roasting furnace.—**Frank Klepetko**, New York, N. Y. Filed Nov. 6, 1905. Issued Mar. 6, 1906. 18 claims.

345 814,299. Roasting furnace.—**Frank Klepetko**, New York, N. Y. Filed Nov. 6, 1905. Issued March 6, 1906. 7 claims.

346 815,516. Apparatus for converting zinc sulphate solution into zinc oxide.—**Chauncey E. Dewey**, Denver, Colo. Filed Jan. 24, 1905. Issued Mar. 20, 1906.

In an apparatus for converting zinc sulphate into zinc oxide, the combination of two independently-revoluble axially-aligned chambers arranged in suitable proximity to each other and having adjacent open extremities, means for delivering heat to one chamber at its extremity remote from the other chamber, means for delivering the zinc-sulphate solution to the chamber remote from the heat generating means, and means exterior to the chambers for transferring the contents of the last-named chamber to its companion chamber. 5 claims.

347 824,181. Roasting furnace.—**Frank Klepetko**. New York. Filed Nov. 17, 1905. Issued June 26, 1906. 14 claims.

348 825,446. Tilting ore roasting furnace.—**Thomas Edwards**, Ballarat, Victoria, Australia. Filed Aug. 7, 1905. Issued July 10, 1906.

349 827,226. Roasting furnace.—**Herbert W. Fox**. Colorado Springs, Colo. Filed Feb. 21, 1906. Issued July 31, 1906.

350 831,166. Roasting furnace.—**Frank Klepetko,** New York, N. Y. Filed Nov. 6, 1905. Issued Sept. 18, 1906.

351 832,248. Ore roasting furnace.—**Thomas Edwards,** Ballarat, Victoria, Australia. Filed Dec. 19, 1903. Issued Oct. 2, 1906.

A water cooled stirring shaft provided with a partition dividing the shaft into two compartments, said partition forming the end of one compartment, a stirrer-arm and means connected to the stirrer-arm for providing circulation through the arm and shaft.

352 837,273. Furnace for sulphating zinc-bearing ores.—**George O. Angell,** Philadelphia, Pa. Filed Dec. 30, 1904. Issued Dec. 4, 1906.

A furnace for roasting and sulphating zinciferous ores, comprising a chamber adapted to operate primarily as a roasting chamber and secondarily as a sulphating-chamber by means to effect the conservation therein of the sulphur gases arising from the roasted blende, said chamber consisting of a basal floor, an upright enclosing wall and an overtop cover therefor with a draft-stack therein, a series of annularly arranged perforated tubes in said upright enclosing wall with transversely disposed passageways in the latter leading from said perforated tubes to the interior of said chamber, for the admission of steam and air thereto, tubular means exterior of the chamber, adapted to lead air and steam to said perforated tubes in the upright inclosing walls, flues leading to said chamber from the base of the furnace, and the fire boxes communicating with said flues.

353 843,825. Roasting furnace.—**Frank Klepetko,** New York, N. Y. Filed Sept. 6, 1904. Issued Feb. 12, 1907. 15 claims.

354 851,639. Process of producing zinc sulphate directly from the ore.—**George O. Angell,** Philadelphia, Pa. Filed Nov. 12, 1904. Issued April 30, 1907.

The process of producing soluble sulphates of zinc and copper direct from zinciferous ores containing sulphides of those metals, which consists in roasting the ore in a suitably chambered furnace to liberate its sulphurous constituent as gaseous sulphur oxides, shutting off applied heat and substantially closing the chamber at this stage, conserving and burning said gases therein in steam saturated suspension and in the presence of oxygen derived from air admitted to such a chamber, to form sulphuric anhydrid to act upon the zinc and copper oxides present in the charge; and finally separating out the resulting soluble sulphates from the charge, in an aqueous solution.

355 858,667. Art of treating ores.—**Robert McKnight,** Pittsburg, Pa. Filed Aug. 28, 1906. Issued July 2, 1907.

The art of reducing ores that contain elements rendering the same refractory, which consists in roasting a mixture of ground ore and salt by means of a superheated oxygen containing gas having a temperature of about 500° C. on entering the furnace; the salt being in sufficient quantity to furnish sufficient sodium to substantially convert the elements rendering the ore refractory, in its crude state into oxysalts of sodium, roasting and agitating the mixture of ore and salt, and simultaneously directing upon the same, a superheated oxygen containing a gas having a temperature of about 500° C., continuing the roast until the elements rendering the ore refractory are thoroughly oxidized and metallic chlorides of metal contained in the ore are produced, collecting and condensing these volatile chlorides when volatilized, and treating the residue of the ore by amalgamation.

356 870,690. Method of roasting suphurous ores.—**Adolf Savelsberg,** Aachen, Germany. Filed Sept. 17, 1906. Issued Nov. 12, 1907.

A method of roasting sulphurous ores consisting in roasting the crude ore in a converter in the presence of a substance (limestone) which, after being heated swells up in contact with water, and thereby partially desulphurizing the same, adding water to the mass thus obtained and thereby destroying the structure resulting from the sintering of the same and roasting the mass again under the action of a blast in a converter. 6 claims.

357 888,502. Rotary furnace applicable for use in roasting ores or the like.—**Woldemar Hommel,** Lee, England. Filed Nov. 23, 1907. Issued May 26, 1908.

358 915,531. Mechanical roasting furnace.—**Roman Von Zelewski,** Engis, Belgium. Filed June 15, 1908. Issued March 16, 1909.

A mechanical roasting furnace comprising a furnace body, a charge-chamber in said furnace body for pre-roasting the ore and a plurality of finish-roasting-chambers for finish-roasting the preroasted ore arranged independently of each other and communicating with said charge-chamber. 8 claims.

359 916,234. Furnace.—**Utley Wedge,** Ardmore, Pa. Filed October 24, 1906. Issued March 23, 1909. 9 claims.

360 926,942. Roasting furnace.—**Hascal A. Hogel,** New York, N. Y. Filed July 27, 1905. Issued July 6, 1909.

361 927,389. Stirring and conveying device for furnaces.—**Utley Wedge,** Ardmore, Pa. Filed Oct. 26, 1908. Issued July 6, 1909.

362 930,254. Ore-roasting furnace.—**Arthur R. Wilfley,** Denver, Colorado, assignor of one-half to Joseph Seep, Titusville, Pa. Filed Nov. 7, 1906. Issued Aug. 3, 1909.

363 939,880. Roasting and like furnace.—**Uteley Wedge,** Ardmore, Pa. Filed Nov. 29, 1907. Issued Nov. 9, 1909.

363a 939,881. Roasting furnace.—**Utley Wedge.** Filed Feb. 24, 1909. Issued Nov. 9, 1909.

364 939,934. Furnace.—**Utley Wedge,** Ardmore, Pa. Filed Feb. 24, 1909. Issued Nov. 9, 1909.

365 939,936. Roasting-furnace.—**Arthur R. Wilfley**, Denver, Colo., assignor of one-half to Joseph Seep, Oil City, Pa. Filed Feb. 19, 1907. Issued Nov. 9, 1909.

366 945,522. Ore-roasting furnace.—**Benjamin Hall**, Nevada City, Cal. Filed May 5, 1909. Issued January 4, 1910.

367 946,178. Furnace.—**Utley Wedge**, Ardmore, Pa. Filed April 16, 1908. Issued Jan. 11, 1910.

367a 947,399. Process for the preparation for zinc oxide for reduction.—**Hermann Pape**, Hamburg, Germany. Filed Mar. 29, 1909. Issued Jan. 25, 1910.

Process of preparing zinc oxide for reduction and transport, consisting in feeding zinc oxide, in the loose condition in which it is obtained from dust chambers or filtering apparatus, into a furnace, and subjecting said oxide, while retained in the furnace, to a temperature of at least 1000° C. and until coagulated into dense, hard and heavy lumps mixed with hard granules.

368 966,277. Ore-roasting furnace.—**Utley Wedge**, Ardmore, Pa. Filed Oct. 18, 1909. Issued August 2, 1910.

369 968,265. Roasting furnace.—**Cyrus Robinson**, New York, N. Y. Filed Sept. 7, 1902. Issued August 23, 1910. 60 claims.

370 968,313. Rotary furnace.—**David Baker**, Philadelphia, assignor to Ladd and Baker, Inc. Filed Mar. 23, 1908. Issued August 23, 1910. 17 claims.

371 969,927. Ore-roaster.—**Arthur R. Wilfley**, Denver, Colo., assignor of one-half to Joseph Seep, Scranton, Pa. Filed Dec. 11, 1908. Issued Sept. 13, 1910. 8 claims.

372 976,175. Ore-roasting furnace.—**John F. Herreshoff**, New York, N. Y., assignor to Nichols Copper Co., New York. Filed July 20, 1909. Issued Nov. 22, 1910.

373 976,525. Treating sulphides or sulphates.—**Utley Wedge**, Armore, Pa., assignor to the Furnace Patent Co., Philadelphia, Pa. Filed Jan. 20, 1909. Issued Nov. 22, 1910.

In the process of desulphurizing, by roasting, ores containing sulphides or sulphates, the mode of facilitating the removal of the sulphur during the later stage of the process, said mode consisting in heating the metal-bearing material during this stage of the process without direct access of the heating gases thereto, and adding to said metal bearing material a reagent whereby any sulphates which may be present will be reduced and the elimination of the sulphur effected without the application of an objectionably high degree of heat. 15 claims.

374 976,769. Annular ore-roasting kiln.—**John Zellweger,** St. Louis, Mo. Filed Jan. 14, 1910. Issued Nov. 22, 1910. 26 claims.

375 979,349. Furnace for roasting ores.—**Xavier de Spirlet,** Brussels, Belgium. Filed April 30, 1910. Issued December 20, 1910.

An ore roaster comprising in combination a series of superposed plates of refractory material spaced apart from each other to form intervening chambers, said plates having openings for successive delivery of one plate to the next lowermost plate, said plates having means for moving the material toward said openings, means for moving certain of said plates with respect to the remaining plates and means forming closed joints at the outer margins of said plates. Patented also in England, No. 10,782 of 1910; in France, No. 415,338.

376 980,717. Stirring device for furnaces.—**Utley Wedge,** Ardmore, Pa., assignor to The Furnace Patent Company, Philadelphia. Filed Jan. 3, 1910. Issued Jan. 3, 1911. 27 claims.

376a 981,880. Process for roasting sulphide ores.—**Charles W. Renwick,** Isabella, Tenn. Filed May 14, 1910. Issued January 17, 1911.

The improved process for roasting metallic sulphide ores, which consists in passing the ores downward through a series of hot roasting ovens, introducing air or oxygen into the lowermost of said series of ovens and causing it to pass upward through said ovens to the uppermost of them, and then reversing the current of said gases from the said upper oven and carrying the said gases downward and reintroducing the same into lower ovens of said series.

377 1,002,401. Production of zinc oxide from ores and zinc residues.—**Waldemar Hommel,** London, England, assignor to Metals Extraction Corporation, Ltd., London. Filed Nov. 30, 1908. Issued Sept. 5, 1911.

The process of recovering zinc from waste zinc furnace distillation residues containing carbonaceous matter, and simultaneously extracting zinc from fresh zinc ore, which consists in roasting the ore, mixing it with the zinc residues containing sufficient carbon to effect the reduction of all the zinc in the mixture, igniting the mixture so as to blow off the zinc (which burns to form zinc oxide) in admixture with other metallic matter, collecting the product thus volatilized, treating it with a solution of sulphurous acid so as to obtain a solution of bisulphite of zinc and precipitating the zinc as insoluble monosulphite which is then calcined to produce zinc oxide. Patented also in England, No. 27,020 of 1909.

378 1,017,839. Recuperative zinc ore roaster.—**John Zellweger,** St. Louis. Issued Feb. 20, 1912.

—Described in Met. & Chem. Eng., vol. 10, p. 307, May, 1912.

379 1,038,408. Furnace for roasting sulphide ores.—**C. C. Meigs,** Woodberry, N. J. Issued Sept. 10, 1912.
—Described in Met. & Chem. Eng., vol. 10, pp. 697-98, Oct., 1912.

380 1,040,071. Roasting furnace with heat-equalizing chambers. —**Utley Wedge.** Issued Oct. 1, 1912.
—Described in Met. & Chem. Eng., vol. 10, p. 817, Dec., 1912.

381 1,061,447. Method of obtaining zinc oxide and sinter from alloys containing zinc.—**Harvey M. Burkey,** Newark, N. J., assignor to Metallurgical Company of America, New York, N. Y. Filed Feb. 29, 1912. Issued May 13, 1913.

> The method of recovering zinc from turnings and other waste metal alloys containing it, which consists in mixing the turnings or the like with fine coal, and igniting and blowing the mixture under temperature conditions which will leave a residual sinter and recovering the zinc as zinc oxide.

—Described in Met. & Chem. Eng., vol. 11, p. 414. July, 1913.

382 1,069,179. Process of roasting ores and recovering zinc therefrom.—**Charles J. Reed,** Philadelphia, Pa. , Filed June 3, 1912. Issued Aug. 5, 1913.

> The process of recovering metals from metallic sulphides, which consists in reducing them to a fine powder, mixing the powder with a metallic oxide, subjecting the mixture to the joint action of heat and an oxygen-containing fluid, dissolving the resulting sulphate, and recovering the metal from the solution.

383 1,070,490. Roasting furnace.—**Frederick Laist,** Anaconda, Mont. Filed Dec. 23, 1912. Issued Aug. 19, 1913.

> In combination with a furnace having a series of superimposed inter-communicating hearths, means for subjecting the charge to an oxidizing roast under direct fire in the hearths forming the upper members of the series, the hearths forming the lower members of the series serving as chloridizing hearths, and means for maintaining a pressure differential between the direct-fired hearth and the adjacent chloridizing hearth.

384 1,072,920. Zinc ore roasting furnace, mechanically rabbled, with tripping device for automatically stopping the rabbles.—**Francis Curnow,** Pittsburg, Kans. Issued Sept. 9, 1913.
—Described in Met. & Chem. Eng., vol. 11, p. 658, Nov., 1913.

385 1,077,010. Improvement in ore (blende) roasting furnaces.— **Xavier de Spirlet,** Belgium. Issued Oct. 28, 1913.
—Described in Met. & Chem. Eng., vol. 11, p. 716. Dec., 1913.

386 1,082,599. Process of chloridizing ores.—**Augustus D. Ledoux,** Summit, N. J. Filed August 13, 1912. Issued December 30, 1913.

The process of chloridizing ores, which consists in successively feeding the ore into and through a furnace, heating the initial part of the charge to induce therein chemical reaction, and thereafter inducing chemical reaction in the following portions of the charge by the heat of the established reaction in the furnace.

387 1,083,252. Process of desulphurizing and briqueting ores.—**William A. Hall,** New York. Filed June 27, 1913. Issued December 30, 1913.

A process of desulphurizing sulphide ore, which comprises subjecting a moving body of said ore, to a non-oxidizing flame projected downwardly thereupon, whereby sulphur is driven off in the elemental condition, and withdrawing the vaporous products from below said body of ore.

388 1,094,953. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed June 19, 1912. Issued April 28, 1914.

389 1,094,954. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed July 16, 1913. Issued April 28, 1914. 9 claims.

390 1,112,853. Manufacture of zinc oxide.—**James A. Singmaster,** Palmerton, Pa., assignor to New Jersey Zinc Co. Filed Jan. 9, 1912. Issued Oct. 6, 1914.

Process of forming sublimed zinc oxide and analogous products, which consists in forming a bed or layer comprising a reducible compound of the zinc or other relatively volatile metal and combustible material, igniting such bed, advancing the same during its combustion through a suitable chamber, simultaneously transmitting a combustion-supporting draft-current through the bed, and collecting the effluent from such bed at successive points along its path of movement. 10 claims.

391 1,112,854. Apparatus for the manufacture of zinc oxide.—**James A. Singmaster,** Palmerton, Pa., assignor to New Jersey Zinc Company. Filed Jan. 18, 1912. Issued October 6, 1914.

A subliming furnace comprising a refractory tunnel structure, a traveling grate surface adapted to move therein, means for transmitting combustion-supporting gas through said traveling grate surface, and a plurality of fume off-takes connected with said structure at intervals along the length thereof. 31 claims.

392 1,114,372. Process of roasting ores.—**Frederick Laist,** Anaconda, Mont. Filed Nov. 22, 1913. Issued Oct. 20, 1914.

In the treatment of ores and other material, the process of subjecting a charge of the ore while traversing a treatment chamber to the action of hot reaction-supporting gases, introducing said gases in a direction conforming to the general direction of movement of the ore in said chamber to prevent overheating of the charge removing the resulting hot calcines from the influence of the said gases, com-

393 1,1[illegible]371. Roasting-furnace.—**Frederick Laist,** Anaconda, Mont. Filed Oct. 15, 1913. Issued Oct. 20, 1914. 6 claims.

394 1,119,483. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed Feb. 28, 1914. Issued December 1, 1914.

395 1,121,226. Dry treatment of ores.—**Wilhelm Buddeus,** Charlottenburg, Germany. Filed February 5, 1914. Issued December 14, 1914.

The treatment of zinc blende ore, containing blende and similar metallurgical products, consisting in mixing the finely divided or disintegrated material with a binding agent such as calcium silicate forming it into briquets and roasting the briquets with fuel in the presence of an air current, and finally directing a burning gas current against the briquets. Patented also in England, No. 29,042 of 1913; in France, No. 466,397.

396 1,131,691. Process for desulphurizing ores.—**Giovanni Fusina,** Genoa, Italy. Filed April 25, 1912. Issued March 16, 1915.

A process for desulphurizing ores which consists in passing a quantity of air through the material in one direction, and then passing a quantity of air and steam through said material in the opposite direction.

397 1,132,684. Roasting of compounds or ores containing zinc.—**Augustin L. J. Queneau,** Philadelphia, Pa. Filed July 19, 1911. Issued March 23, 1915.

The method of dead-roasting zinc blende, which consists in introducing the blende into a roasting chamber, maintaining an oxidizing roasting atmosphere therein while keeping the charge in agitation, heating the lining of the roasting chamber by an electric current and thereby maintaining the temperature of the charge at the roasting point for zinc blende and establishing neutral conditions between the lining and charge during the roasting operation. Patented also in England, No. 15,460, of 1912; in France, No. 445,233; in Germany, No. 288,648. See item 280.

398 1,133,068. Rake-operating mechanism for ore-roasting furnaces.—**John J. Simmonds,** Iola, Kans., assignor to the Simmonds Engineering Company, Iola. Filed July 16, 1914. Issued March 23, 1915.

399 1,142,795. Production of zinc sulphate.—**Ramon Bonastre Llopart,** Cordoba, Argentina. Filed April 2, 1915. Issued June 15, 1915.

The method of producing zinc sulphate which consists in mixing a blende comprising zinc sulphide and sulphide of iron with substances containing zinc and oxygen, heating them to 400° to 500° C. in air free from strong currents. 6 claims.

400 1,143,438. Ore roasting or drying furnace.—**Harry Mackenzie Ridge,** London, England. Filed October 6, 1913. Issued June 15, 1915. 7 claims.

—Described in Eng. & Min. Jour., vol. 100, p. [illegible]1. Aug. 14, 1915.

401 1,154,601. Extraction, purification, and electrolytic precipitation of metallic zinc from smelter-fumes, zinc ores and the like.—**Otto Best,** San Francisco, Cal. Filed Sept. 16, 1911. Issued, Sept. 28, 1915.

In the extraction of metallic zinc from zinc fumes, or the like, the preliminary step of obtaining a zinc salt suitable for forming the electrolyte, which comprises subjecting the fumes to a purifying roast, in the presence of sulphates, at a low temperature, thereby rendering the fumes filterable, and leaching with a small excess of sulphuric acid.

402 1,162,532. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed May 3, 1911. Issued November 30, 1915.

—Described. Min. & Sci. Press, vol. 112. p. 246. Feb. 12, 1916.

—Described. Jour. Soc. Chem. Ind. vol. 35. p. 124. Jan. 31, 1916.

pleting the treatment of the calcines thus removed without further application of heat and conducting the gases from the final treatment, to the charge traversing the treatment chamber aforesaid. 8 claims.

403 1,162,533. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed Oct. 23, 1912. Issued November 30, 1915.

404 1,162,534. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed Oct. 22, 1913. Issued November 30, 1915.

405 1,169,444. Treating metallic sulphides.—**Utley Wedge,** Ardmore, Pa. Filed June 5, 1913. Issued Jan. 25, 1916.

The continuous process of producing metal from sulphur compounds containing the same consisting in first subjecting the compound at a temperature sufficient to vaporize the sulphur, to an atmosphere containing a reagent which will oxidize the metal without promoting the oxidation of the sulphur, and then continuing the subjection of the oxide thus formed to a reducing atmosphere at a temperature sufficient to convert the oxide to metallic form.

—Described in Min. & Sci. Press. vol. 112, p. 484. Apr. 1, 1916.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 315. Mar. 15, 1916.

405 1,170,375. Treating ores.—**Utley Wedge,** Ardmore, Pa. Filed Oct. 7, 1911. Issued Feb. 1, 1916.

—Described. Jour. Soc. Chem. Ind. vol. 35, p. 364. Mar. 31, 1916.

407 1,170,376. Metallurgical furnace.—**Utley Wedge,** Ardmore, Pa. Filed Jan. 15, 1913. Issued Feb. 1, 1916.

—Described. Jour. Soc. Chem. Ind. vol 35, p. 364. Mar. 31, 1916.

408 1,171,583. Ore-roasting apparatus.—**Harrison T. Benson,** Denver, Colo., assignor of one-half to **Winfield S. Barnes,** Philadelphia, Pa. Filed Aug. 11, 1915. Issued Feb. 15, 1916.

409 1,172,321. Process for recovering zinc from zinciferous materials.—**Friedrich Carl Wilhelm Timm,** Hamburg, Germany. Filed Oct. 7, 1913. Issued Feb. 22, 1916.

The process for recovering zinc from zinciferous materials which consists in causing gas containing free oxygen to pass through a hot mixture of zinciferous materials and solid carbonaceous substances during a comparatively short time, then withdrawing the mixture from the effect of the gas passing through it, then re-arranging the mixture in a practically even density, then causing the free oxygen-containing gas to pass again through the mixture and repeating this working whereby the zinc is freed from the zinciferous materials in different periods, the heat produced by passing the free oxygen-containing gas through the mixture being so regulated as to produce an un-molten, sintered residue. Patented also in England, No. 22,519 of 1913; in France, No. 463,330; in Germany, No. 268,427.

—Described in Met. & Chem. Eng., vol. 14, p. 666. June 1, 1916.

410 1,172,470. Ore-roasting furnace.—**William H. Motter,** Denver, Colo. Filed May 19, 1913. Issued Feb. 22, 1916.

411 1,173,354. Water-cooled hollow shaft for ore-roasting furnaces.—**Ernst Jensen-Valdal,** Copenhagen, Denmark, assignor to Aktieselskabet Dansk Svovsyre- & Superphosphat-Fabrik, Copenhagen, Denmark. Filed Jan. 3, 1912. Issued Feb. 29, 1916.

412 1,181,183. Roasting of sulphur bearing ores.—**Harry H. Stout,** New York, N. Y., assignor to General Chemical Company, New York. Filed July 31, 1914. Issued May 2, 1916.

413. 1,181,184. Roasting furnace for sulphur-bearing ores.—**Harry H. Stout,** New York N. Y., assignor to General Chemical Company, New York. Filed July 31, 1914. Issued May 2, 1916.

414 1,183,172. Process of roasting zinc-blende.—**Charles A. H. De Saulles,** New York, N. Y. Filed Oct. 17, 1914. Issued May 16, 1916.

The method of treating zinc blende for recovering metallic zinc which comprises roasting the blende, adding carbon to the roasting charge at the latter end of the roasting operation and regulating the air admission so as to produce a temperature not exceeding 1,000°

C. and thereby obtaining a reduction and dissociation of the sulphates present without volatilizing any of the metals, and finally treating the resultant roast in a suitable furnace to reduce the zinc to a metallic state.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 744. July 15, 1916.

415 1,195,424. Roasting Furnace.—**Utley Wedge,** Ardmore, Pa., assignor to The Furnace Patent Company, Philadelphia. Filed Jan. 20, 1916. Issued August 22, 1916. 16 claims.

—Described. Jour. Soc. Chem. Ind. vol. 25, p. 1067. Oct. 31, 1916.

416 1,195,425. Metallurgical furnace.—**Utley Wedge**, Ardmore, Pa., assignor to The Furnace Patent Company, Philadelphia. Filed June 24, 1911. Issued Aug. 22, 1916.

—Described. Jour. Soc. Chem. Ind. vol. 25, p. 1067. Oct. 31, 1916.

417 1,208,246. Furnace and allied structure.—**Utley Wedge,** Ardmore, Pa. Filed Jan. 12, 1914. Issued December 12, 1916.

—Described. Jour Soc. Chem. Ind. vol. 36, p. 142. Feb. 15, 1917.

418 1,208,247. Furnace.—**Utley Wedge,** Ardmore, Pa. Filed Feb. 11, 1914. Issued Dec. 12, 1916.

419 1,208,248. Feeding device for furnaces.—**Utley Wedge,** Ardmore, Pa. Filed Feb. 28, 1914. Issued Dec. 12, 1916.

420 1,208,249. Metallurgical furnace.—**Utley Wedge**, Ardmore, Pa. Filed Nov. 21, 1914. Issued Dec. 12, 1916.

421 1,208,250. Metallurgical furnace.—**Utley Wedge**, Ardmore, Pa. Filed Mar. 1, 1915. Issued Dec. 12, 1916.

422 1,210,852. Mechanical roasting furnace.—**Wilhelm Schefczik.** Hamborn-on-the-Rhine, Germany. Filed May 22, 1914. Issued January 2, 1917.

423 1,213,922. Zinc-furnace.—**George Londress** and **Leyland Rogers,** Clarksburg, W. Va. Filed June 27, 1914. Issued Jan. 30, 1917.

A zinc dross furnace comprising a series of fire boxes, a dross compartment and a spiral flue surrounding said dross compartment and communicating with and connecting each of said fire boxes.

—Described in Jour. Soc. Chem. Ind. vol. 36, p. 343-44. Mar. 31, 1917.

424 1,258,934. Process of extracting metals from their ores.—**Charles C. Nitchie,** Depue, Ills., assignor to The New Jersey Zinc Company, New York. Filed Nov. 19, 1915. Issued March 12, 1918.

The method of treating ores, fumes and other metalliferous material containing lead, zinc and iron, which comprises heating such material with ammonium sulphate to a temperature sufficient to convert the zinc and iron into sulphates and to drive off the ammonia, then heating to a higher temperature to decompose the iron sulphate without decomposing the zinc sulphate, and extracting the zinc sulphate from the resulting product, whereby a zinc sulphate solution is obtained relatively free from lead, and iron and a lead-containing residue is obtained substantially free from zinc.

—Described in Met. & Chem. Eng. vol. 18, p. 550. May 15, 1918.

425 1,273,844. Process for roasting ore.—**Charles H. Fulton,** Cleveland, Ohio, assignor to Metallurgical Laboratories, Inc., Chicago, Ill. Filed Aug. 19, 1916. Issued July 30, 1918.

A process of roasting finely divided sulphide ores comprising forming a mixture of pulverized ore and preheated air thereby raising the temperature of the ore to the ignition point, conveying such mixture of air and ore together slowly while maintaining the suspension and temperature of the ore until the required degree of desulphurization is attained and then separating the ore from gases and air. 11 claims.

Great Britain

426 12,512 of 1899. Process for roasting sulphide ores.—**E. C. H. Pape** and **C. A. L. W. Witter,** Hamburg, Germany.

Roasting mixed sulphides in a powdered form sprayed into contact with the heating furnace.

427 16,161 of 1899. Furnace for sulphide ores.—**J. Armstrong,** London.

"Improved form of reverberatory furnace for the inventor's process for treating zinc-lead sulphide ores."

428 16,312 and 16,388 of 1899. Treatment of zinc-lead sulphides. —**J. Armstrong,** London.

Modifications on the inventor's process for treating zinc-lead sulphides and its special application for zinc alone.

429 21,213 of 1899. Roasting furnace.—**W. A. Koneman** and **W. H. Hartley,** London.

"A roasting furnace where the heating gases are drawn through the ore by suction."—E. & M. J.

430 10,105 of 1901. Improved process for the treatment of mixed ores and compounds, for the extraction or separation of lead and zinc therefrom.—**C. H. T. Haverman,** Paris. Issued May 15, 1901.

"Mixed ores or sludges are mixed with carbon and heated in a reverbatory furnace connected to condensation chambers.... .... "—J. S. C. I.

431 5,016 of 1903. Roasting blende.—**A. Kunze** and **K. Danziger,** Kattowitz, Silesia.

Roasting mixed blende and pyrite in such a way that the pyrite oxidizes before the blende, then removing the iron by leaching, after which the blende is more fit for the zinc furnace.

432 22,900 of 1905. Roasting process.—**E. Enke,** Kattowitz, Silesia.

"In sulphatizing ores, especially zinc ores, adding acid sodium sulphate, and heating the mixture with the exclusion of air to a temperature just sufficient to decompose the ferrous sulphate."—E. & M. J.

433 4,199 of 1906. Zinc roasting ores.—**L. Brunet,** Paris.

"Method of roasting complex zinc ores so that sulphate of zinc is formed; then dissolving out with sulphurous acid and acting on barite so as to produce a lithopone paint, consisting of sulphite of baryta and oxide of zinc."—E. & M. J.

434 5,655 of 1906. Metallurgy of zinc.—**H. A. Leaver** and **C. Buch,** London.

"Improved process for recovering zinc oxide from flux skimmings of zinc by means of lime."—E. & M. J.

435 3,374 of 1907. Mechanical roasting furnaces for roasting zinc sulphide, etc.—**A. Landsberg** and **A. Roitzheim,** Stolberg, Germany.

436 12,708 of 1915. Mechanical roasting furnaces.—**A. Zavelberg,** Hohenlohehuette, Germany.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 1161, Nov. 31, 1916.

437 100,259 of 1916. Automatic charging devices for roasting and like furnaces.—**A. Mond,** London. From Metallbank und Metallurgische Ges., Frankfort, Germany.

—Described in Jour. Soc. Chem. Ind., vol. 36, p. 203, Feb. 28, 1917.

Germany

438 299,528. Process of desulphurizing zinc ores.—**Aktien-Gesellschaft f. Bergbau, Blei- und Zinkfabrikation zu Stolberg.** Sept. 1, 1908.

"The feature of the process is the combined use of a blast, and movement of the ore during roasting."—J. S. C. I.

439 236,089. Mechanical roasting furnace with several horizontal, circular, super-imposed roasting chambers, connected with each other alternately at the circumference and in the center.—**Xavier de Spirlet,** Brussels, Belgium. April 29, 1910.

—Described. diagr. Zeits. f. angewandte Chem., vol. 24, p. 1493. Aug. 4, 1911.

440 237,034. Process for the complete roasting of zinc blende and other sulphide ores.—**R. G. Max Liebig**, Godesburg-am-Rhein, Germany. June 11, 1910.

"To completely desulphurize zinc blende, it is necessary to apply additional heat towards the end of the roasting. According to the present patent, highly heated air is led directly over the ore."—J. S. C. I.

—Described in Zeits. f. angewandte Chem., vol. 24, p. 1653. Sept. 1, 1911.

441 242,312. Process for oxidizing roasting of sulphide zinc ores in combustion gases containing oxygen and aqueous vapors.—**W. Borchers**, Aix-la-Chapelle, **Rudolph Schenck**, Breslau, and **Felix Thomas**, Aix-la-Chapelle. May 13, 1910.

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—Described in Jour. Soc. Chem. Ind., vol. 31, p. 237. Mar. 15, 1912.

442 244,131. Rotary tubular oven for the roasting of zinc ores. **Paul Schmieder**, Lipine, Upper Silesia, Germany. May 26, 1910.

—Described in Zeits. f. angewandte Chem., vol. 25, p. 640. Mar. 29, 1912.

443 278,443. Process for the roasting of blende ores or smelter products on a movable grate.—**Wilhelm Buddeus**, Charlottenburg, Germany. Feb. 27, 1913.

The blende is briquetted with a salt, which prevents the disintegration of the briquet during roasting.

444 286,620. Sulphatizing roasting of ores and metallurgical products.—**Wilhelm Buddeus**, Charlottenburg, Germany. Sept. 7, 1913.

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444a 306,790. Continuous process for the chloridizing roasting of zinc and copper bearing ores and residues in the blast furnace.—**Wilhelm Buddeus**, Berlin. Issued July 10, 1918.

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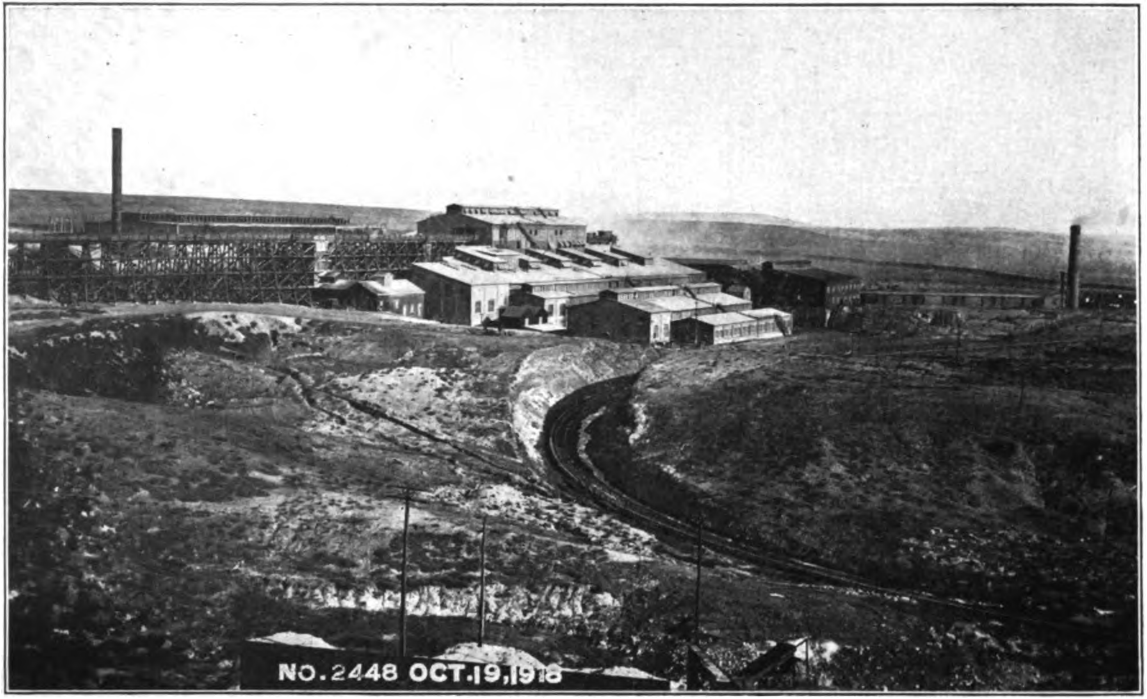

LEACHING DIVISION, GREAT FALLS ELECTROLYTIC ZINC PLANT, ANACONDA COPPER MINING CO.

The black building in the right center is the Dryer Division, containing rotary dryers for drying the residue from the Leaching Division. The monitor or the Electrolyzing Division is visible in the left foreground.

See also under Electrolytic Zinc, as nearly all the articles on electrolysis include descriptions of leaching methods.

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Ammcnia—Carbon Dioxide Process

446 Apparatus for ammonia process. diagr. Met. & Chem. Eng. vol. 12, pp. 139-40. Feb., 1914.

Bretherton's Patent 1,082,797. Recovery of zinc and copper by decantation.

447 An experimental plant for treating refractory copper-zinc ores.—**Frank L. Wilson.** Calif. Jour. Tech., Feb., 1914.

448 Extraction of zinc from mixed ore.—**S. E. Bretherton.** Eng. & Min. Jour., vol. 87, pp. 666. Mar. 27, 1909.

Use of ammonia and carbonic acid.

449 Leaching of zinc ore at the Afterthought Mine.—**Frank L. Wilson.** Min. & Sci. Press, vol. 108, p. 453. Mar. 14, 1914.
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450 Preparation of ore containing zinc for the recovery of other metals, such as silver, gold, copper and lead by the elimination and subsequent recovery of the zinc as a chemically pure zinc product.—**S. E. Bretherton.** Amer. Inst. Min. Eng., Trans., vol. 47, pp. 82-90. 1913.
—Same. Recovery of metals from ore containing zinc. Min. Wld., vol. 40, pp. 51-53. Jan. 10, 1914.

451 The successful treatment of zinc sulphide ores.—**Frank L. Wilson.** Canad. Min. Jour., vol. 35, p. 127. Feb. 15, 1914.

452 Sulphide ores of Mexico applicable to leaching with ammonia and carbon dioxide solutions for the recovery of their zinc content.—**Frank L. Wilson.** illus. Mex. Min. Jour., vol. 18, pp. 107-08. Mar., 1914.

453 The treatment of complex ores by the ammonia-carbon-dioxide process.—**S. E. Bretherton,** Amer. Inst. Min. Eng. Trans., vol. 49, pp. 802-08. 1914.

"Grind the ore, roast, regrind, leach zinc with ammonia and carbon dioxide, precipitate copper from solution, distill ammonia and carbon dioxide from the solution, thereby precipitating basic zinc carbonate which can be calcined to oxide."

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454 Zinc extraction from Colorado sulphide ores.—**Frank L. Wilson.** Min. Wld., vol. 40, pp. 337. Feb. 14, 1914.

Treatment of zinc-copper ores at Afterthought plant.

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455 Zinc extraction from complex ores.—**S. E. Bretherton** and **Frank L. Wilson.** diagr. Eng. & Min. Jour., vol. 98, pp. 117-18. July 18, 1914.

Experimental work being carried on at Afterthought Mine, California. 84.9% zinc soluble in a 20.79% ore. 87.95% zinc soluble in a 30% ore. Prolonged sulphatizing roast, followed by leaching with ammonia-carbon-dioxide.

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Difficulties presented by complex zinc-copper ores at Bully Hill and Afterthought and experimental methods in use at latter plant.

Bisulphite Process

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As conducted at the works of the British Metals Extraction Co., Llansamlet, Wales.

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471 Aufbereitung schwer schmelzbarer Zink-Bleierze durch Behandeln derselben mit Ammonium sulfat oder Ammoniumchlorid. Metallurgie, vol. 7, pp. 245-46. Apr. 22, 1910.

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Roasting and leaching zinc-lead ores. Isherwood's German Patent 238,890.

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Best's patent 1,154,602. Purification of zinc sulphate solution. "In the recovery of zinc from ores and other materials containing the same in acid-soluble form, the method of obtaining a solution which comprises extracting the zinc with sulphuric acid, and treating the resulting solution before separation from the undissolved material with lime in amount insufficient to precipitate the zinc."

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488 Hydrometallurgy of zinc. (Metallurgy of zinc in 1913).—**W. R. Ingalls.** Eng. & Min. Jour., vol. 97, p. 104. Jan. 10, 1914.

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Three methods for treating flue dust of high zinc sulphate content.

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Betts patent 1,066,245. Addition of chromate or chromic acid, permanganate or permanganic acid prevents solution of iron in the ore.

494 Lixiviation of lead and zinc. diagr. Eng. & Min. Jour., vol. 102, p. 591. Sept. 30, 1916.

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Dewey's Patent 900,088. Conversion of zinc oxide into zinc sulphite; particularly treatment of mixture of galena, pyrite and blende carrying silver.

496 Manufacture of pure solutions of sulphate of zinc from zinc ores. Mex. Min. Jour., vol. 19, p. 364. Dec., 1914.

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501 Recovering zinc from leaching solutions. Eng. & Min. Jour., vol. 100, p. 62. July 10, 1915.

Buddeus's patent 1,120,683. Recovery of zinc from waste solutions obtained in copper leaching, by precipitating the zinc and ferrous iron by means of burnt lime, etc.

502 Removal of cadmium from zinc ores. Eng. & Min. Jour., vol. 99, p. 659. April 10, 1915.

Rigg's patent 1,129,904. Zinc ore containing cadmium oxide is leached with water containing enough sulphuric acid to convert the cadmium oxide into cadmium sulphate.

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503 Roasting and leaching concentration slimes tailings.—**Lawrence Addicks.** illus., diagr. Amer. Inst. Min. Eng., Trans., vol. 52, pp. 765-82. 1915.

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507 Treatment of refractory zinc-lead ores.—**P. C. C. Isherwood.** diagr. Min. Wld., vol. 40, pp. 963-64. May 23, 1914.

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508 Ueber die Geschwindigkeit der Aufloesung von Zinkblende und Bleiglanz in Verduennter Schwefelsaeure.—**Felix Rosenkraenzer.** graphs. Zeits. f. anorgan. Chem., vol. 87, pp. 319-34; vol. 88, p. 452. June 23, Aug. 25, 1914.

Rapidity of solution of blende and galena in dilute sulphuric acid.

509 Verarbeitung zinkarmer Erze, besonders von Galmei. Metallurgie, vol. 9, pp. 309-10. May 8, 1912.

Working up carbonate ores of low zinc content, leaching with sulphurous acid, and smelting. German patent 238,292, by Gilbert Dantin, Lyons, France.

510 Verfahren zum Auslaugen von zinkhaltigen Stoffen mit Chlor bei Gegenwart von Kohle. Metallurgie, vol. 7, pp. 284-85. May 8, 1910.

Method of leaching zinc-bearing materials with chlorine, in the presence of carbon. German Patent 216,361, by Guido Mojana, Milan, Italy.

511 Verfahren zur Erzeugung von reinem Zinkoxyd oder reinem metallischen Zink durch Behandlung gereinigter Loesungen von Zinksalzen mit Ammoniumsulfit unter Regenerierung des verwendeten Ammoniumsulfits und Gluehen des erhaltenen Zinksulfits. Metall u. Erz. vol. 12, pp. 299-300. July 22, 1915.

German patent 285,617; by H. W. de Stucklé. Process for the production of pure zinc oxide, or pure metallic zinc by working refined solutions of zinc salts with ammonium sulphite, with regeneration of the used ammonium sulphite and calcination of the zinc sulphites.

512 Verfahren zur Verarbeitung von Silber-Blei-Zinkerzen durch Schmelzen derselben mit Chlorzink oder seinen Doppelsalzen und Faellen des Bleis aus waessriger Loesung. Metall u. Erz., vol. 11, pp. 432-33. June 22, 1914.

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513 Zinc chloride from zinc-bearing ores. Met. & Chem. Eng., vol. 18, p. 550. May 15, 1918.

Cameron's Patents, 1,261,695-96.

514 Zinc digester and filter. diagr. Met. & Chem. Eng., vol. 11, p. 54. Jan., 1913.

P. C. C. Isherwood's patent 1,043,939. "The operation is similar in many respects to that of a chlorination barrel, but is only one step in a process which involves solution of zinc in sulphuric acid, and ultimate electrolysis."

515 Zinc, gold silver from ores. Electrochem. & Met. Ind., vol. 4, p. 35. Jan., 1906.

Nicholas's Patent 805,577. Treatment of ores, mattes, slimes, etc., by mixture with water and sodium chloride, forming zinc chloride, which is leached.

516 Zinc hydrometallurgy. Eng. & Min. Jour., vol. 97, p. 809. Apr. 18, 1914.

Bett's Patent 1,066,245.

517 Zinklaugerei. Zeits. f. Elektrochem., vol. 3, pp. 13-14. July 5, 1896.

German Patent 87,398, by Carl Hoepfner. Zinc leaching. The ore is roasted to oxide; sulphuric acid and calcium chloride are added, forming zinc chloride, which is satisfactory for electrolysis.

PATENTS ON LEACHING

United States

518 444,997. Process of treating zinc ores.—**William West,** Denver, Colo. Filed December 13, 1889. Issued January 20, 1891.

The process of eliminating zinc from complex ores, which consists in roasting the ore to form sulphurous acid gas and oxidize the zinc, then cooling this gas to a temperature of 180° F. or below and passing the same in gaseous form in conjunction with steam and without oxidation into sulphuric acid through a previously roasted charge to form soluble sulphite of zinc and then immediately leaching out and separating the zinc sulphite with water at a temperature below 180° F.

519 457,256. Process of obtaining sulphate of zinc from zinciferous ores.—**Charles F. Croselmire,** Newark, N. J. Filed March 31, 1888. Issued August 4, 1891.

That improvement in the process of obtaining sulphate of zinc from zinciferous ores where iron and alumina are present, which consists in pulverizing the ore and roasting it, placing it in a dilute acid solution, and then injecting into or through said solution steam, superheated steam, or hot air with chloride of lime for the purpose of depositing any trace of iron or alumina that may be present.

520 489,873. Method of producing zinc oxide from sulphite or sulphate of zinc.—**Robert F. Nenninger,** Newark, N. J. Filed Sept. 21, 1892. Issued Jan. 10, 1893.

The method of recovering oxide of zinc from a solution of sulphate or sulphite of zinc, which consists in precipitating with lime, collecting the precipitate and boiling it with a concentrated solution of zinc sulphate, filtering, evaporating the filtrate to dryness and finally leaching with water.

521 497,473. Process of treating complex or sulphide ores.—**Walter R. Ingalls** and **Francis Wyatt,** New York, N. Y. Filed Dec. 28, 1892. Issued May 16, 1893.

The process of treating complex sulphide ores, which consists first in subjecting the ore to a sulphatizing roasting and recovering the driven off sulphur in the form of sulphuric acid; second, lixiviating the roasted ore with said sulphuric acid and water, and removing the iron from the solution if necessary; third, precipitating the zinc from said solution in the form of carbonate, or carbonate and hydroxide, by the use of sodium carbonate, and subsequently converting the same into zinc oxide; fourth, evaporating the sodium sulphate obtained from the zinc sulphate solution, and heating the same with sodium chloride and coal to convert it into sodium sulphide; fifth, converting the sodium sulphide into bi-carbonate of soda by dissolving the same in water and treating the solution with carbonic acid gas and recovering the sulphur in the form of sulphuric acid as described and lastly, converting the bi-carbonate of soda into sodium carbonate by heating the same, to drive off the hydrogen and carbonic acid gas.

522 512,362. Process of preparing solutions carrying salts of zinc.—**Parker C. Choate,** New York, N. Y., assignor to the Electrical Zinc Co., of New Jersey. Filed June 4, 1892. Issued Jan. 9, 1894.

The process of forming a solution carrying salts of zinc which consists in forming a sulphate solution of the soluble elements of the ore and recovering the same therefrom by evaporation and crystallization, heating the crystallized product to drive off the salts of metals more volatile than zinc and convert those less volatile than zinc into compounds insoluble in water and finally treating the mass with water to dissolve the zinc element.

—Described in Met. & Chem. Eng., vol. 10, p. 62. Jan., 1912.

523 513,490. Process of treating zinc-lead-sulphide ores.—**Stephen H. Emmens,** London, England. Filed Nov. 28, 1892. Issued Jan. 30, 1894.

The process of treating lead sulphide ores carrying gold or silver, which said process consists in, first, finely comminuting the ore, secondly, roasting the same in an oxidizing atmosphere, thirdly, leaching out such roasted ore with water containing ferrous sulphate, fourthly, leaching such once-leached ore with an aqueous solution of ferrous and ferric sulphates, fifthly, leaching such twice-leached ore with water containing ferrous sulphate, and sixthly, removing iron from the zinc sulphate solution obtained by the first and second of the said leachings by mixing such solutions together and heating them.

524 516,016. Treatment of ores of zinc.—**Walter R. Ingalls** and **Francis Wyatt,** New York, N. Y. Filed October 3, 1893. Issued March 6, 1894.

The process of treating ores of zinc which consists, first in subjecting the ore to an oxidizing roasting; second, lixiviating the roasted ore with water and sulphuric acid; third, separating one fourth of the zinc sulphate solution thereby formed from the rest and precipitating the zinc from said separated portion by means of a sulphide of an alkaline base; fourth, evaporating the remainder of the zinc sulphate solution to dryness and mixing the precipitated sulphide therewith; and lastly heating the mixture in a suitable furnace whereby sulphurous anhydride gas is evolved.

525 518,890. Process of extracting zinc from ores.—**Ludwig Klöz,** Leadville, Colo. Filed April 24, 1893. Issued April 24, 1894.

The process of treating zinc ores which consists first, in roasting the ores, and conducting the sulphurous acid gases from the roast into a suitable tower, and absorbing them into water; second, heating the solution so formed to set free part of the sulphurous acid gas, and scattering the remainder of the solution to set free the balance of the gas; third, reabsorbing the gas so set free in water to form a concentrated solution; fourth, leaching the ores or furnace products with this solution, and fifth, scattering the resulting zinc sulphite solution with steam, to dispel the sulphurous acid and precipitate the zinc in the form of the sulphite.

526 541,447. Process of reducing zinc slimes.—**Hugh W. Watts** and **Alonzo Coan,** Boulder, Colo. Filed Oct. 22, 1894. Issued June 18, 1895.

Consists in first treating with dilute sulphuric acid to remove metallic zinc, washing the residue to remove the soluble salts and remaining acid, and boiling the residue thus formed with concentrated sulphuric acid to dissolve the cyanide of zinc and other salts thereof which are insoluble in the dilute acid.

527 544,612. Process of manufacturing zinc.—**Atkinson Crossley,** Talywain, England. Filed May 14, 1895. Issued August 14, 1895.

The process for the manufacture of zinc oxide which consists in adding sulphuric acid to the metallic ores or compounds, heating the mixture and converting the lead present to an insoluble salt, and depositing any gold or silver present, then diluting with water and converting the other metals present to soluble salts, filtering off the clear liquor, then treating the clear acid liquor filtered off with an alkaline sulphide, precipitating the copper as copper sulphide, then filtering the liquor from the precipitate, treating with an alkali until neutral, passing chlorine into it until all manganese and iron present form manganic and ferric oxides which are thrown down by a slight excess of alkali, adding an excess of alkali to bring the zinc oxide into solution, and then precipitating the zinc oxide and filtering off the liquor therefrom.

528 547,587. Method of extracting zinc from complex ores.—**Carl V. Petraeus,** Joplin, Mo., assignor to Oliver P. Picher. Filed March 31, 1891. Issued October 8, 1895.

The method of separating zinc from complex ores where it is found as a sulphate or sulphite which consists in crushing the ore, roasting it, dissolving out the soluble zinc salts in water, adding a solution of sulphuric acid to dissolve out any zinc oxide, introducing live steam to the mixture of ore and solvents to thoroughly mix and heat them, separating the solution of sulphate of zinc from the insoluble parts of the ore, adding chloride of calcium to the solution to convert the zinc into a chloride, separating the solution of zinc chloride from the precipitated calcium sulphate and finally adding quick lime to the solution of zinc chloride to precipitate the zinc as zinc oxide.

529 570,861. Apparatus for leaching.—**Lewis D. Armstrong,** Lock Haven, Pa. Filed June 25, 1891. Issued November 3, 1896.

530 595,513. Method of preparing zinc ores and zinciferous ores for smelting.—**Edgar A. Ashcroft,** Grays, England. Filed March 20, 1896. Issued December 14, 1897.

The improvement in the method of preparing zinc ores and zinciferous lead ores for smelting, which consists in leaching the finely ground ore with a hot solution of ferric sulphate, thereby dissolving out the zinc and precipitating the iron as ferric hydrate in the residue to serve as a flux in the smelting operation.

531 602,295. Treating solutions or ores containing zinc for recovering zinc as oxides.—**Edgar A. Ashcroft,** Newcastle, New South Wales. Filed September 4, 1896. Issued April 12, 1898.

Consists (a) obtaining from the zinc bearing ore or solution solutions of sulphate; (b) adding zinc oxide and stirring the mixture until a pasty consistency is obtained; and (c) heating the resulting product for the purpose of converting it into zinc oxide, sulphurous or sulphuric acid gas being disengaged.

532 611,917. Treatment of zinc and copper ores.—**Walter. J. Koehler,** Broken Hill, New South Wales, assignor to the Broken Hill Proprietary Company, Ltd., Melbourne, Victoria. Filed Nov. 7, 1896. Issued October 4, 1898.

The method of treating oxidized zinc-bearing ores, which consists in heating said ores with an admixture of ammonium sulphate, thereby converting the oxides into sulphates and liberating the free ammonia-gas, then leaching by water the sulphates so obtained, and then precipitating the zinc from its solution in the form of zinc hydrate by passing through it the liberated ammonia gas and regenerating the sulphate of ammonia.

533 647,989. Process of extracting zinc from substances containing same.—**Thomas Ryan, Jr.**, Flint, and **Newton Hughes**, Baglilt, England. Filed Dec. 26, 1899. Issued April 24, 1900.

The process of extracting zinc from substances containing the same consisting in subjecting the substances to the action of a caustic alkali the various steps of the dissolving being so carried out that the solution of caustic alkali is brought in contact with several successive portions of raw material, and the various portions of raw material are each successively treated with different portions of caustic solution, precipitating any lead present by galvanic action, securing the removal of organic matters and iron manganese and silicon by the addition of caustic lime and bleaching powder, and finally precipitating the dissolved zinc in the form of zinc oxide or zinc hydroxide by the addition of carbonic acid.

534 648,809. Process of making anhydrous zinc chloride.—**Oscar J. Steinhart, Julius L. F. Vogel,** and **Henry E. Fry,** London, England. Filed April 10, 1899. Issued May 1, 1900.

The process herein described of manufacturing dehydrated zinc chloride without the loss of chlorine and formation of zinc oxychloride, which consists in heating a solution of zinc chloride in an air-tight vessel and maintaining a vacuum therein until the solution is boiled, watery vapor driven off and anhydrous zinc chloride remains in a fused state with only a trace of zinc oxide.

535 652,072. Treatment of Ore.—**Guy de Bechi,** Paris, France. Filed Jan. 24, 1899. Issued June 19, 1900.

The method of treating complex ores, for the recovery of copper, zinc and lead consisting in subjecting the ore to a chloridizing roasting, condensing the vapors and gases evolved, treating the roasted ore and the acidulated water containing the condensed vapors and gases with calcium chloride to precipitate soluble sulphates and sulphuric acid as insoluble calcium sulphate, then lixiviating the ore with the acidulated water to obtain a solution of zinc and copper salts, and fractionally precipitating zinc and copper from the said solution as hyhrated oxides by successive additions of lime, substantially as described.

536 654,804. Process of obtaining oxide and carbonate of zinc from materials containing zinc.—**Gilbert Rigg,** Swansea, England. Filed May 6, 1899. Issued July 31, 1900. 12 claims.

Consists in leaching the zinciferous material with a solution of ammonia and carbon-dioxide wherein the carbon-dioxide is in such proportion to the ammonia as to impart to the latter an approximately-maximum zinc-dissolving capacity.

537 656,497. Process for treating zinc-bearing complex ores for recovery of zinc or other metals therefrom.—**Guy de Bechi,** Paris. Filed May 1, 1899. Issued Aug. 21, 1900. 9 claims.

Consists in separately roasting the ore and an alkali chloride in the presence of air and steam, conveying the sulphurous and sulphuric vapors thus derived from the ore over and in contact with the said chloride during the roasting to obtain hydrochloric-acid fumes, condensing the acid fumes, lixiviating the roasted ore, with the acid liquor thus obtained to produce a solution of metallic chloride, and successively precipitating the metals of the metallic chloride as hydrates by successive additions of alkali.

538 659,338-9-40. Process of extracting zinc and copper from their ores.—**Caleb G. Collins,** New York. Filed Oct. 30, 1899. Issued Oct. 9, 1900.

The process consists in exposing the comminuted ore to the action of a solution of sodium sulphate containing sodium bisulphate, sodium chloride and hydrochloric acid (salt-cake and niter-cake solution) in proportion to the contained copper and zinc, but sufficient in strength to dissolve only copper and zinc therefrom; and subsequently recovering these metals from the solution.

539 663,759. Process of producing solutions of zinc chloride, etc.—**Carl Hoepfner,** Frankfort, Germany. Filed Nov. 18, 1897. Issued Dec. 11, 1900. 7 claims.

Consists in reacting upon an oxide or insoluble salt of zinc in presence of water with sulphurous acid to form soluble zinc bi-sulphate, precipitating from the bisulphate so obtained the insoluble monosulphite of zinc, and treating the latter with a chloride of an alkali metal to form zinc chloride.

540 672,637. Process of treating zinc-bearing ores for obtaining zinc, etc.—**Sherard O. Cowper-Coles,** London, England, assignor to the Cowper-Cowles Metal Extraction Syndicate, Ltd., Mellanear Haeyle, England. Filed July 23, 1898. Issued April 23, 1901.

A process for the treatment of complex zinc ores, such as those known as Broken Hill ore, consisting in crushing, screening and roasting the ore, then placing it in leaching vats, then treating it with a weak solution of sulphuric acid to abstract the zinc and copper, then passing such solution containing zinc sulphate and copper sulphate through a body of carbon and an electropositive metal to recover the copper, and then electrolyzing the remaining solution to recover the zinc.

541 678,210. Process of treating complex ores.—**James W. Worsey,** St. Helen's, England. Filed Sept. 17, 1900. Issued July 9, 1901.

Process for the production of zinc oxide from the complex sulphide ores, comprising partial removal of the sulphur by calcination of the ore, mechanical disintegration of the ore, addition of sodium nitrate to the ore, formation of zinc sulphate by boiling the ore with dilute sulphuric acid, roasting the product in a closed furnace, lixiviation of the roasted product with weak sodium-sulphate solution, removal of copper where present from the sodium-sulphate solution, precipitation of the zinc from the said solution by means of lime and sublimation of the zinc in an oxidizing atmosphere.

542 682,794. Process of obtaining zinc solutions free from iron and manganese compounds.—**Friedrich A. Gasch,** Hönningen-on-the-Rhine, Germany. Filed Dec. 19, 1899. Issued Sept. 17, 1901.

The process of obtaining zinc solution substantially free from iron and manganese, which consists in treating zinciferous roasted pyrites with concentrated sulphuric acid and roasting the product resulting therefrom at about a temperature of 400° C., and mixing it while still hot with a suitable oxidizing agent and finally leaching the mixture.

543 695,306. Separation of the constituents of complex sulphide ores.—**Max M. Haff,** New York, N. Y., assignor to the Ampere Electro-Chemical Co., Jersey City. Issued March 11, 1902.

The process consists in heating mixed sulphides of zinc and lead with sulphate of an alkali metal, treating the resultant mass with a dissolving agent to dissolve the zinc sulphate and the alkali-metal sulphate, while leaving the lead sulphate undissolved and adding barium hydrate to the mixed solution to precipitate zinc hydrate and barium sulphate.

544 697,898. Process of purifying zinc-bearing ores.—**Carl R. P. Steinau,** Cleveland, Ohio. Filed Jan. 12, 1901. Issued April 15, 1902.

The process of purifying zinc-bearing solutions containing copper, lead, arsenic, cadmium and other metals kindred with zinc, which consists in treating such solutions with zinc powder, that is to say, with a mixture of about seventy-five parts of zinc and about twenty parts of zinc oxide, to precipitate the copper, lead, arsenic and cadmium, and to simultaneously reduce the amount of any free acid the solution may contain.

545 704,036. Process of separating alkali-metal sulphates from mixed solutions.—**Carl Hoepfner,** Frankfort-on-the-Main, Germany. Issued July 8, 1902.

A method of separating alkaline suphates from mixed solutions, which consists in rapidly cooling the same by allowing them to flow into a cold solution of a suitable chloride, thereby preventing the formation of double salts.

546 704,641. Process of extracting zinc or other metals from their ores.—**Carl Hoepfner,** Frankfort-on-the-Main, Germany. Filed July 27, 1900. Issued July 15, 1902.

The process, which consists in reacting on a material containing an oxygen compound of metals insoluble in water and whose chlorides are soluble in a solution of alkali-metal chloride with sulphurous acid and an aqueous solution of alkali-metal chloride, whereby a solution is formed containing a chloride of a metal. Patented also in England, Nos. 11,724 for 1894; 5,662 for 1895; 8,449 for 1895; 24,573 for 1896; 15,873 for 1900. German Patent, No. 155,065 for 1902.

547 707,506. Method of treating mixed sulphide ores.—**Erminio Ferraris,** Monteponi, Italy. Filed July 28, 1902. Issued August 19, 1902.

The process of decomposing mixed sulphide ores by means of concentrated sulphuric acid without the aid of extraneous heat. Patented also in England, No. 12,349 of 1901.

548 715,023. Process of treating zinc sulphide ores.—**John C. Clancy** and **Luke W. Marsland,** Sydney, New South Wales, Australia. Filed Feb. 16, 1901. Issued Dec. 2, 1902.

A process for the elimination of zinc and the recovery of lead, silver or other metals from sulphide ores consisting essentially in the following step by step operations: (a) roasting the pulverized ore with the addition of lead sulphate at such degree of heat as will not volatilize the lead contained in the ore or the added lead sulphate: (b) transferring the roasted ore while still very hot immediatety from the roasting furnace into a vat containing a solution of sulphuric acid and water and thereby causing the solution to become heated to the boiling point, or thereabout: (c) agitating the whole mixture in the said vat during the process of charging, lixiviating, extracting, and dissolving of the zinc in the same: (d) recovering lead oxide by concentration from the ore and solution while undergoing treatment in the said solution: (e) converting the lead oxide so recovered into lead sulphate to be used for adding to succeeding charges of ore to be roasted in the furnace: (f) conducting the residual ore and solution into a settling vat and separating the solution from the ore by drawing off the zinc from the solution so separated and recovering from the said solution the sulphuric acid therein contained for use in treating succeeding charges of roasted ore; and (h) recovering the lead, silver and other metals contained in the residual ore by smelting the same in any suitable smelting-furnace. Patented also in England, No. 4,039 of 1901.

—Described in Jour. Soc. Chem. Ind., vol. 20, p. 481. May 31, 1901.

549 715,771. Treatment of zinc ores.—**Francis Ellershausen** and **Richard T. Western,** London, England. Filed August 4, 1902. Issued Dec. 16, 1902.

The process for the treatment of zinc ores and other zinciferous matter, consisting in acting on said ore or other matter with hydric ammonic sulphate in solution to produce double sulphate of ammonia and zinc, agitating ammonium sulphate with slaked lime, drawing off the supernatant solution of ammonia, and treatlng the double sulphate of ammonia and zinc previously formed, with said ammonia solution to precipitate the hydroxide of zinc. 5 claims. Patented also in England, No. 26,166 of 1901; France, No. 324,062. Compare also U. S. Patent 700,311 (item 1006).

550 718,554. Method of extracting zinc.—**William G. Waring,** Tyrone, Pa. Filed June 14, 1902. Issued January 13, 1903.

The process consisting in leaching crude zinciferous ores, residues or products, by a leaching agent consisting of dilute acidulated water containing not more than 1.5 per cent. free sulphuric acid together with an indefinite amount of dissolved ferric sulphate; precipitating the metals of the copper group by agitation with a slight excess of a soluble sulphide and finally separating the zinc by means of hydrogen sulphide. 6 claims. Patented also in England, No. 28,925, of 1902.

551 733,000. Process of obtaining sulphide of zinc from copper slag.—**Ferdinand Brünjes,** Langelsheim, Germany. Filed August 11, 1902. Issued July 7, 1903.

A process of treating slags containing zinc oxides and sulphides of other metals capable of forming soluble chlorides, which consists in adding to the slag dilute hydrochloric acid to convert the sulphides into chlorides, liberate hydrogen sulphide and thereby precipitating zinc sulphide, separating the precipitate, and adding to the solution the sulphide of a metal of the alkaline earths to convert any zinc chloride into sulphide.

552 740,372. Process of extracting zinc from sulphide ores.—**Charles Rogers,** Kew, Victoria, Australia. Filed October 21, 1901. Issued September 23, 1903.

The process of extraction and recovery of zinc-containing sulphide ores or tailings, which consists in subjecting the same to a partial sulphatizing roast, discharging the same while hot into water, leaching the same with said water and with dilute sulphuric acid, subjecting the leached ores or tailings to a second sulphatizing roast, releaching the same with the lixivium from the former leaching and repeating said operations till sufficient zinc and sulphur are removed.

553 741,653. Process of treating lead, silver, or zinc ores.—**Solomon Ganelin,** Berlin. Filed Jan. 25, 1900. Issued October 20, 1903.

Consists in mixing said substances with a molten salt capable of dissolving the said oxides from the rest of the ore and then separating the metallic substances from said salt and the rest of the ore. Patented also in England, No. 24,469, of 1899.

554 751,712. Process of producing hydrated sulphide of zinc.—**Victor Bermont,** Paris, France. Filed May 6, 1902. Issued February 9, 1904.

A process for the preparation of pure zinc salts from the oxygen-bearing compounds, consisting in treating by ammonia the ore previously crushed and in separating by filtration, after decantation, the solution from the solid part; purifying the ammoniacal liquor produced consisting in precipitating the metals other than the zinc in the condition of insoluble sulphides formed when the soluble sulphide is gradually added to the first solution, in separating by filtration, after decantation, these precipitates from the liquid mass so as to obtain as precipitable salts only zinc salts, and in precipitating from this solution perfectly pure salts of zinc by the addition of soluble salt giving an insoluble salt of zinc. Patented also in England, No. 6,752, of 1902.

This process relates especially to the treatment of calamine and smithsonite.

555 754,643. Process of separating iron pyrites from zinc blende.—**Karl Danziger,** Zawodze, near Kattowitz. Filed May 29, 1903. Issued March 15, 1904.

A process for separating iron pyrite from zinc-blende, to the action of air moisture and heat and extracting the ferrous salt, which has been formed by the oxidizing action by water. Patented also in England, No. 5,016 of 1903.

556 781,133. Process of treating zinc sulphide ores containing iron.—**Chauncey E. Dewey,** Denver, Colorado., assignor to the American Zinc and Chemical Company, Denver, Colo. Filed April 2, 1904. Issued January 31, 1905.

The process for the treatment of zinc sulphide ores containing iron, consisting in first roasting the ore, whereby the zinc is converted into zinc sulphate and zinc oxide, and the iron present into ferric oxide, as far as practicable; second, placing the ore thus prepared in water; and third, maintaining the ore in suspension in the solution by the introduction of sulphurous gas whereby the zinc oxide present is formed into zinc sulphite, and the latter into zinc sulphate by reaction with the ferric oxide.

557 803,472. Extraction and purification of zinc.—**Alfred V. Cunnington,** Winnington, Eng. Filed July 20, 1904. Issued Oct. 31, 1905.

In the process of obtaining zinc from oxidized ores treating them with zinc chloride solution and hydrochloric acid with constant stirring, the solution being kept about neutral during the operation and separating the solution from the spent residue.

In the process of dissolving out zinc from its ores containing arsenic by means of a solution of a salt of zinc and the acid of said salt, neutralizing the solution by the addition of an alkali and then separating the arsenic by means of freshly precipitated ferric hydroxide. Patented also in England, No. 4,706 of 1904; in France, No. 350,580.

557a 805,577. Treatment of ores and the like.—**James Nicholas,** Waterloo, England. Filed May 27, 1905. Issued November 28, 1905.

The treatment of materials containing zinc, lead and precious metal, by mixing the pulverized materials with water, and with a chloride, then heating the mixture, leaching this so-treated mixture with water, reducing the metallic compounds contained in the leached residue to a metallic state, agitating the molten lead and precious metal with aluminium, cooling, then separating the alloy of precious metal with aluminum from the lead.

558 832,341. Process of treating complex sulphide ores.—**William G. Rumbold** and **George Patchin,** London. Filed Feb. 3, 1906. Issued October 2, 1906.

The process for the extraction of zinc and other metals from complex oxidized ores containing zinc, consisting in passing over successive lots of crushed ore a solution consisting of ferric sulphate, sulphuric acid, sodium chloride and water, until such solution becomes saturated with dissolved matter, such dissolved matter consisting of the zinc and also the copper, cadmium, manganese, nickel, cobalt, antimony, lead, tin, or any or all of these metals wnen contained in said ores, a small proportion of ferric sulphate being employed in the solution in relation to a large amount of sulphuric acid whereby the ferric sulphate is continuously decomposed and regenerated until all the free acid has become neutralized. Patented also in England, no. 2,532 of 1905; in France, no. 363,025.

559 836,587. Wet method of extracting copper, zinc, etc., from their ores.—**Denis Lance,** Paris. Filed August 7, 1905. Issued November 20, 1906.

The process of extracting and concentrating metals from ores consisting in treating ores with nitrosulphuric acid and decomposable metallic chlorides, in causing nitrosulphuric acid to react upon decomposable metallic chlorides to form nitrochlorides, in causing the said nitrochlorides to react upon the metal contained in said ore to form the chloride of such metal, in causing the previously added nitrosulphuric acid to react upon the said metal chloride to form the sulphate of the metal contained in said ore. 16 claims.

560 850,965. Apparatus for producing alkali hydrates and zinc sulphide.—**Charles Ranson,** Brussels, Belgium, assignor to Henry William De Stuckle, Dieuze, Germany. Filed Sept. 6, 1905. Issued April 23, 1907.

An alkali apparatus comprising a closed receptacle adapted to contain alkali-forming reagents, heating means and agitating means for facilitating reaction therein, and means for feeding liquid reagent thereto controlled by the pressure of evolving gas in said receptacle. Patented also in France, no. 353,496.

561 863,411. Treatment of sulphide ores containing zinc.—**Ralph W. E. McIvor,** London, England, assignor to Metals Extraction Corporation, Ltd. London, England. Filed Feb. 2, 1906. Issued August 13, 1907.

The process of extracting zinc from sulphide ores containing the same, which consists in converting by heat the zinc contained in the ore into soluble sulphate of zinc and oxide of zinc, washing out the soluble sulphate with water, adding to the solution thus obtained calcium chloride, drawing off the solution of chloride of zinc so formed, adding the latter to the treated ore, digesting the whole to form an oxychloride of zinc, decomposing said oxychloride by an alkaline hydrate, and removing the precipitated zinc compound and washing the same. Patented also in England, No. 23,977 of 1905; in France, no. 362,677.

562 863,417. Process to utilize the inferior calamines.—**Francisco S. Moyano,** Aguilas, Spain. Filed Oct. 20, 1906. Issued Aug. 13, 1907.

A process of producing zinc oxide from ore containing carbonate of zinc, which consists in reducing said carbonate to oxide of zinc by calcination, heating the zinc oxide with chloride of calcium to produce zinc chloride, removing zinc chloride in solution from the remaining portions of the ore, transforming the zinc chloride into a carbonate of zinc by the action of the carbonate of magnesium, and finally transforming the resulting carbonate of zinc into oxide by the aid of heat.

563 875,424. Process for the treatment of zinciferous ores and metallurgical products.—**James H. Gillies,** Auburn, Victoria, Australia. Filed Aug. 20, 1906. Issued Dec. 31, 1907.

Consists of first roasting the ore to form a maximum amount of sulphate of zinc, and a minimum amount of sulphates of iron and copper, then feeding such roasted ore downwardly into a vessel in which there is an upwardly moving current of dilute sulphuric acid, withdrawing the gangue and undissolved mineral particles from the said vessels at the bottom, and withdrawing the solution of zinc sulphate and other soluble salts together with the slimes and certain mineral particles at the top, and finally subjecting the said solutions and the slimes and certain mineral particles to alternate settling and washing of the solids. Patented also in England, no. 1,004 of 1906.

564 875,425. Apparatus for leaching ores and the subsequent separation of the liquids from the solids.—**James H. Gillies,** Auburn, Victoria, Australia. Filed Aug. 20, 1906. Dec. 31, 1907.

The combination with a double walled vessel forming an annular space surrounding an internal space, the said walls being stepped or zigzag in vertical section and shaped as inverted cones at the bottom, of a discharge pipe from the bottom of said annular space and a discharge pipe from the bottom of the said internal space, and an inlet pipe for solution leading into the bottom of the annular space. Patented also in England, no. 994 of 1906.

565 875,866. Process of obtaining zinc oxide from zinc ores.—**Henry L. Sulman,** London, England. Filed Oct. 30, 1906. Issued Jan. 7, 1908.

The process of obtaining zinc oxide from zinc ores which consists in converting the zinc into oxide, treating the ore with sulphurous acid solution to dissolve the zinc as bisulphite, separating the bisulphite solution from the residue, adding to the solution zinc oxide which will remove sulphurous acid and precipitate the zinc as monosulphite, separating the zinc monosulphite from the liquor and drying and calcining the same to produce zinc oxide, and collecting the sulphurous acid evolved for repeated use. 9 claims.

566 880,775. Treatment of complex sulphide ores.—**Guy De Bechi,** London, England, assignor of one-half to Reginald Wynn Rucker, London, England. Filed April 9, 1907. Issued March 3, 1908.

A cyclical process for treating complex sulphide ores containing lead and zinc consisting in grinding or pulverizing the ore to the condition of an impalpable powder, treating the same with a solution of ferric sulphate, filtering the solution of ferrous sulphate and zinc sulphate so formed from the insoluble lead residue, converting the ferrous sulphate to ferric sulphate by oxidation and subjecting them to acid fumes evolved from the calcination of the zinc sulphate obtained from a previous operation, crystallizing out the zinc sulphate and separating the same from the ferric sulphate solution, calcining the zinc sulphate, subjecting the zinc and lead compounds separately to the usual metallurgical treatment and using the regenerated ferric solution for the treatment of a further quant'ty of ore. Patented also in England, no. 9,339 of 1906.

567 900,088. Treating oxide of zinc.—**Frederic P. Dewey,** Washington, D. C. Filed June 8, 1898. Issued Oct. 6, 1908.

The process of dissolving oxide of zinc, which consists in adding it in small portions at a time to water containing sulphurous acid, so that the free sulphurous acid remains always in excess.

568 914,730. Process of treating complex sulphide ores.—**George E. Kingsley,** Toronto, Can., assignor to A. E. Kingsley, Denver, Colo. Filed Dec. 23, 1907. Issued March 9, 1909.

In the treatment of complex ores, such as ores containing galena, zinc and antimony, immersing the ores in a dilute solution of nitric acid of a strength six and one-quarter to seven and one-quarter per cent, and heated to one hundred and seventy degrees Fahr.

569 918,749. Apparatus for use in solution and precipitation process.—**Woldemar Hommel,** London, England, assignor to Metals Extraction Corporation, Ltd. Filed November 30, 1908. Isued April 20, 1909.

570 925,190. Treatment of refractory zinc-lead ores.—**Percy C. C. Isherwood,** Harrow, England. Filed July 8, 1907. Issued June 15, 1909.

A process for extracting zinc and copper from refractory zinc lead ores consisting in washing the ore, treating it in a concentrated solution of ammonium sulphate and then heating the residues with solid ammonium sulphate at a temperature below redness. 8 claims. Patented also in England, no. 16,364 of 1906.

571 938,055. Method of treating poor sulphide ores.—**Alfred Holdsworth,** Barnsbury, London, England. Filed Nov. 1, 1907. Issued October 26, 1909.

The process for treating sulphide ore containing silver, zinc, copper, iron, etc., which consists in mixing with the finely divided ore material, an amount of sulphuric ac'd of substantially 60° Baumé determined by the composition of the material, and substantially in the proportion of one molecule of acid to each atom of sulphur present in the ore, calcining the mixture with free access of air to decompose the unstable sulphates into oxides and oxidize the sulphur, leaching out the soluble sulphates with water, subsequently leaching out certain of the oxides with sulphuric acid sufficiently weak not to attack other oxides present, and collecting the sulphur oxides for the production of sulphuric acid.

572 966,209. Obtaining zinc oxide from zinc ores and products. —**Woldemar Hommel** and **Henry Livingstone Sulman,** London, England, assignors to The Metals Extraction Corporation, Ltd., London. Filed Nov. 9, 1907. Issued August 2, 1910.

Consists in roasting the ore out of contact with the fuel, volatilizing from the roasted ore the zinc contents in the form of dry oxide, together with the other metallic matters, collecting the dry product thus volatilized, treating it with a solution of sulphurous acid so as to obtain a solution of bisulphite of zinc, precipitating the zinc as insoluble monosulphite and calcining the monosulphite to produce zinc oxide. 10 claims.

573 966,389. Wet process for the treatment of ores.—**Henry Thomas Durant, Henry Livingstone Sulman,** and **Woldemar Hommel,** London, England. Filed November 11, 1909. Issued August 2, 1910.

The method of extracting zinc from its ores which consists in commingling the ore with a suspending liquid in forcing said ore and liquid through a conduit of restricted capacity and against maintained pressure by a jet of sulphurous acid whereby all portions of the ore are subjected to a uniform chemical action and in subsequently filtering the solution and precipitating the zinc. See also item 468.

574 999,420. Process of separating zinc or zinc oxide.—**George Wannschaff** and **Josef Savelsberg,** Papenburg, Germany. Filed Mar. 23, 1911. Issued August 1, 1911.

The method of separating zinc or zinc oxide from material containing the same, which comprises leaching the material with a heated aqueous solution of zinc chloride, cooling the solution to obtain a precipitate containing zinc oxide and zinc chloride, leaching the precipitate with water to remove the greater part of the zinc chloride, treating the residue with lime to convert all of the zinc salts therein into zinc oxide. Patented also in England, no. 5,577 of 1911; in France, no. 426,897.

575 1,009,750. Extraction of metals from their ores.—**Woldemar Hommel** and **Henry Durant,** London, England, assignors to The Metals Extraction Corporation, Ltd., London. Filed June 25, 1910. Issued Nov. 28, 1911.

The cyclic process for the extraction of zinc from its sulphide ores in which the only reagents employed are water and those supplied by the ore itself, which consists in roasting the ore to drive off gases containing sulphurous acid, cooling said gases and bringing them in contact with a mixture of the roasted ore and water to effect the solution of the zinc as sulphite and thereafter submitting said sulphite solution to the action of the hot gases from the ore roasting furnace whereby insoluble zinc monosulphite is precipitated, the said hot gases being enriched in sulphurous acid and cooled ready for the further treatment of the mixture of roasted ore and water. Patented also in France, no. 417,208 of 1910.

—Described in Met. & Chem. Eng., vol. 10, p. 179. Mar., 1912.

576 1,011,962. Treatment of refractory zinc-lead ores.—**Percy C. C. Isherwood,** Leytonstone, England. Filed April 8, 1910. Issued December 19, 1911.

A process of treating refractory zinc lead ores consisting in roasting the ores and leaching them with a solution containing less than the theoretical amount of the sulphuric acid necessary for complete solution of the zinc oxide contained in the ore when under ordinary conditions of temperature and pressure, at a high temperature and presure of from 50 to 200 lbs. per square inch. 11 claims. Patented also in England, no. 21,584 of 1909; in France, no. 420,510; in Germany, no. 238,890. See also items 507 and 586.

—Described. Met. & Chem. Eng., vol. 10. p. 179. Mar. 1912.

577 1,013,511. Process of producing pure zinc sulphide and thiosulphates.—**Pierre Pipereaut** and **Antony Vila,** Paris, France. Filed September 15, 1908. Issued January 2, 1912.

The process for treating zinc sulphide ore to recover zinc sulphide in a granular form, which consists in lixiviating the ore with caustic alkali solution, thereby forming alkali zincate, heating to boiling, adding sufficient free sulphur to precipitate the metals other than zinc in the form of sulphides, and separating the same from the solution prior to the precipitation of the zinc sulphide, and then adding, in small amounts, sufficient free sulphur to precipitate the zinc present, while keeping the liquid hot.

578 1,029,932. Process of treating zinc-bearing ore.—**James O. Johnstone, Buffalo,** New York. Filed July 20, 1911. Issued June 18, 1912.

The process of treating ores containing zinc and barites which consists in heating the ore in the presence of a reducing agent which converts the barium sulphate to barium sulphide, and subsequently leaching the mixture whereby the barium sulphide will go into solution and leave insoluble zinc sulphide. 9 claims.

579 1,041,060. Process for the treatment of refractory zinc-lead ores.—**Andrew Gordon French,** Nelson, British Columbia, Canada. Filed September 30, 1911. Issued October 15, 1912.

The process of separating zinc and manganese from complex ores which consists in first roasting the ore to drive off the excess of sulphur,then adding to the mass crushed bisulphate of sodium in the proportion from 5 to 15 per cent of bisulphate of sodium to the original weight of the ore before it has been calcined, then applying heat to the mixture to bring the mass to a dull red heat at a temperature below the sinter forming point, and subsequently recovering the soluble sulphates formed by the reaction, by lixiviation. 6 claims. Patented also in England, no. 22,077 of 1912.

—Described in Met. & Chem. Eng., vol. 10, pp. 816-17. Dec., 1912.

579a 1,043,939. Filtering apparatus.—**Percy Claude Cameron Isherwood,** Leytonstone, England, assignor to Refractory Zinc Ore Treatment Company, a Corporation of N. Y. Filed Feb. 18, 1910. Issued Nov. 12, 1912.

580 1,063,356. Manufacture of sulphide of zinc.—**Joseph Koetschet** and **Joannes Claude Antoine Meyer,** Lyons, France. Filed Dec. 1, 1908. Issued June 3, 1913.

A process for the manufacture of sulphide of zinc, comprising subjection of a solution of crude zinc sulphate to preliminary treatment with sulphurated hydrogen with the object of precipitating impurities, filtration of the liquid, and subjection of the same as a concentrated solution to intimate and prolonged contact with sulphureted hydrogen to precipitate zinc sulphide.

581 1,066,245. Production of zinc sulphate.—Anson G. Betts, Troy, N. Y. Filed Dec. 9, 1912. Issued July 1, 1913.

In extracting zinc from material containing zinc in the form of oxide, the treatment of said material with sulphuric acid in the presence of an oxidizing agent stronger in its oxidizing action than ferric sulphate. See also items 493 and 516.

582 1,069,178. Process of recovering zinc.—**Charles J. Reed**, Philadelphia, Pa. Filed June 3, 1912. Issued August 5, 1913.

Consists in treating material containing zinc with an excess of sulphuric acid, treating the resulting solution with an oxidizing agent, purifying the oxidized solution with an excess of zinc-containing substance, further purifying the solution and recovering the zinc from the purified solution.

583 1,071,856. Treatment of metal-bearing solutions.—**Edgar Arthur Ashcroft,** Balestrand, Norway. Filed April 25, 1912. Issued September 2, 1913.

The process for the treatment of metal bearing solutions to obtain the zinc therefrom which consists in adding to the solution a cyanogen compound and subsequently heating the mixture, whereby the zinc is obtained in the form of an insoluble compound. 9 claims.

583a 1,074,203. Deposition of metallic salts from solutions containing them.—**Harry Rees,** Llansamlet, Glamorgan, Wales, and **Henry Livingstone Sulman,** London, assignors to the Metals Extraction Corporation, Ltd., London. Filed August 18, 1911. Issued Sept. 30, 1913.

A process for depositing monosulphite and sulphate of a metal from a solution containing bisulphite and sulphate of the metal, which consists in subjecting a continuously moving thin film of the solution to the action of hot gases from a coke fire. 8 claims.

584 1,082,766. Collector.—**Morely Punshon Reynolds**, Cleveland, Ohio, assignor to W. S. Tyler Company. Filed September 16, 1912. Issued December 30, 1913.

585 1,082,797. Means for the maintenance of gas in confinement.—**Sidney Elliott Bretherton,** Berkeley, Cal. Filed Oct. 9, 1912. Issued Dec. 30, 1913.

586 1,089,412. Treatment of refractory zinc-lead ores.—**Percy Claude Cameron Isherwood,** Bushey Heath, England. Filed Oct. 18, 1912. Issued March 10, 1914.

A process for the recovery of zinc from prepared refractory zinc lead ore, consisting in roasting the ore, then leaching the ore under basic conditions with a quantity of fresh sulphuric acid less than that which is necessary for the complete solution of the zinc contained therein and producing a highly basic solution of zinc, afterward leaching the ore with the remainder of the fresh sulphuric acid necessary for the complete solution of the zinc under conditions of high temperature and pressure, and adding the solution of zinc thus produced in the second leaching of the ore to the fresh sulphuric acid used in the first leaching of a fresh quantity of ore. Patented also in England, no. 22,855 of 1912. See also item 507.

587 1,091,269. Separation of metals from zinc-bearing ores or compounds.—**Edgar Arthur Ashcroft,** Balestrand, Sogn, Norway. Filed Apr. 25, 1912. Issued March 24, 1914.

The process for obtaining metals from solutions containing them which consists in precipitating the metals as hydrates with ammonia adding excess of ammonia to dissolve the zinc, lead, manganese and other hydrates present soluble in excess, separating the precipitated hydrates from the solution, precipitating the manganese by a slow stream of chlorine and separating it from the remaining solution, precipitating the zinc hydrate by adding to the solution a further quantity of purified zinc chloride, mixing with the precipitated zinc hydrate the ammonium chloride separated from the solution by crystallization, thereafter distilling the mixture firstly at a low temperature to drive off the water, secondly at about 300° C. to convert the zinc to fused zinc chloride, and to drive off the ammonia, recovering the ammonia, and thirdly raising the temperature to about 500° C. to drive off the excess of ammonium chloride. Patented also in England, no. 19,257 of 1911; in France, no. 446,755.

588 1,110,790. Apparatus for making and filtering solutions, applicable in the extraction of metals from ores and for like purposes.—**Percy C. Isherwood,** Bushey Heath, England. Filed June 26, 1914. Issued September 15, 1914.

589 1,118,894. Process of producing pure zinc oxide.—**Henry William De Stuckle,** Paris. Filed Feb. 18, 1914. Issued November 24, 1914.

A cyclical process of producing pure zinc oxide, which consists in reacting upon a dissolved zinc salt with ammonium sulphite in presence of caustic ammonia or ammonium carbonate, calcining the precipitated zinc sulphite and utilizing the evolved sulphur dioxide for regenerating the ammonium sulphite. Patented also in England, no. 28,188 of 1913; in France, no. 465,816.

590 1,120,683. Treatment of zinc-lyes.—**Wilhelm Buddeus,** Charlottenburg, Germany. Filed Nov. 26, 1913. Issued December 15, 1914.

The treatment of zinciferous lyes containing ferrous iron, consisting in adding to the lye a base in sufficient quantity to precipitate all the zinc and all the ferrous iron, drying the filtered and washed precipitate, thereby causing complete oxidation of the ferrous iron into the ferric state, and treating the dried mass with an acid to dissolve out the zinc. Patented also in England, no. 25,967 of 1913.

591 1,129,904. Removal of cadmium from zinc ores.—**Gilbert Rigg,** Palmerton, Pa., assignor to The New Jersey Zinc

Company, New York. Filed Dec. 3, 1914. Issued March 2, 1915.

The method of removing cadmium from zinc ores, which consists in first roasting the ore and lixiviating with water in the presence of zinc sulphate in amount sufficient to convert the cadmium to be removed into soluble cadmium sulphate, the zinc sulphate present being derived in part from the roasted ore, and in part from the addition of sulphuric acid to the lixiviating water, and drawing off the resulting solution from the ore.

592 1,135,981. Process of making pure zinc oxide and recovering substances from waste and like liquors.—**Waldemar Asef,** Philadelphia, Pa. Filed July 19, 1913. Issued April 20, 1915.

The process of recovering pure zinc oxide from a zincate solution which consists in decomposing the solution by the addition of a solution of a salt or salts, thereby precipitating pure zinc oxide and forming a caustic alkali solution in which said salt or salts are inert, recovering the pure zinc oxide and evaporating the mother liquor to recover the caustic and the salt or salts. 8 claims.

593 1,137,874. Process of leaching ores.—**Jasper A. McCaskell,** Salt Lake City, Utah. Filed June 2, 1914. Issued May 4, 1915.

The process of leaching ores and then regenerating the solvent, said process consisting essentially in producing chlorine gas electrolytically from metallic sodium chlorides, using the chlorine thus produced to chlorinate the metals in the ore that is being treated, and subsequently electrolyzing an aqueous solution of the chlorides in the cathode side of an electrolytic cell, thereby regenerating the original sodium chloride, the metals in the solution being deposited on the cathode of said cell. 5 claims.

593a 1,144,480. Process for treating complex sulphide ores.—**George E. Kingsley,** Spokane, Wash. Filed Jan. 22, 1915. Issued June 29, 1915.

In the treatment of complex sulphide ores, the process of immersing the ores in a dilute solution of nitric acid of a strength of five per cent. or less, and heated to one hundred and seventy-six degrees F., whereby a nitrate is produced and sulphur in its natural state.

593b 1,144,481. Process of treating mixed sulphide ores.—**Erich Langguth,** Neerpelt, Belgium. Filed Sept. 11, 1913. Issued June 29, 1915.

The process of treating sulphide ores which consists in treating said ores with molten zinc chloride, adding to the melt a limited quantity of zinc approximately that required to reduce the silver and only a part of the lead, then pouring the resultant molten mass into water whereby the remaining lead constituents of the ore become dissolved, then separating the dissolved constituents from the undissolved residue, and then extracting the lead from the solution. 6 claims.

594 1,154,602. Hydrometallurgy of zinc.—**Otto Best,** San Francisco, Cal. Filed March 26, 1913. Issued September 28, 1915.

In the recovery of zinc from ores and other materials containing the same in an acid-soluble form, the method of obtaining a solution which comprises extracting the zinc with sulphuric acid and treating the resulting solution before separation from the undissolved material with lime in amount insufficient to precipitate the zinc. 32 claims.

595 1,157,153. Process for the industrial separation of lead and zinc contained in the state of sulphides in ores.—**Guy De Bechi,** London. Filed Mar. 29, 1913. Issued October 19, 1915.

A process for the industrial separation of lead and zinc contained in the state of sulphides in ores consisting in reducing the ore to an impalpable powder, treating said powder by a mixture of ferric sulphate, ferric aoid and nitric acid, whereby sulphides are transformed into sulphates with formation of free sulphur, and separating the zinc solution from the lead sulphate by filtration. Patented also in England, no. 4,246 of 1913; in France, no. 454,255.

596 1,173,467. Process of treating zinc ores.—**C. C. Titus** and **W. J. Barenscheer,** Helena, Mont., assignors to New England Electro-Chemical Metals Company, Boston. Issued Feb. 29, 1916.

The dry ore is chloridized in the presence of sodium chloride, the soluble chlorides extracted, and the metal contents of the solution precipitated, with ultimate replacement of their chlorides by sodium chloride. The resulting sodium chloride solution is electrolized, the evolved chlorine being used to chloridize fresh ore, and the chlorinated anode-liquor to extract the chloridized mass.

—Described in Jour. Soc. Chem. Ind., vol. 35, pp. 475-76, April 29, 1916.

597 1,177,396. Desulphurizing method for treating refractory ores.—**Edward Hale Dickie,** Goldroad, Ariz. Filed Jan. 25, 1915. Issued March 28, 1916.

The method of treating refractory ores consisting in mixing the finely ground ore with a solution of caustic soda and potassium acetate agitating the mixture in the presence of a metallic value precipitant, and finally removing the solution.

598 1,190,765. Extraction of zinc from its ores or products.—**Henry Thomas Durant,** London, England, assignor to The Metals Extraction Corporation, Ltd. London. Filed May 4, 1914. Issued April 25, 1916.

Consists in roasting the ore so as to produce mainly sulphate of zinc, passing the furnace gases through circuit solution containing metallic sulphates but fairly free from sulphites so as to produce a solution of sulphur dioxide, and leaching the ore with the said solution of sulphur dioxide whereby the first runnings from the leached ore are rich in sulphates, while the solution subsequently obtained by the action of the solvent liquor on the ore contains metallic sulphites. 11 claims. Patented also in England, nos. 21,581 and 22,761 of 1913.

599 1,182,320. Method of treating flue products.—**Francis C. Ryan,** Hammond, Ind., assignor of one half to The United States Metals Refining Company, Chrome, N. J. Filed Feb. 24, 1914. Issued May 9, 1916.

The process of treating oxidized mineral bearing material, comprising roasting the material with a sufficient amount of strong sulphuric acid to insure an acid condition of the roasted material, adding water to the roasted material and boiling under an acid condition, filtering, reducing the acidity of the solution to a slightly acid condition to precipitate impurities and separating the solution for a subsequent treatment for zinc.

600 1,184,585. Process of treating ores.—**Edward Snyder,** Pioche, Nev. Filed Mar. 31, 1915. Issued May 23, 1916.

A process of treating oxidized ores containing lead, zinc and other metals, which comprises leaching the oxidized ore with a hot liquid containing an alkali sulphate, and containing sulphuric acid in amount sufficient to dissolve a part only of the zinc contained in said ore, separating the resulting liquid from the ore, and rendering the same slightly alkaline to precipitate zinc hydroxide, treating the digested ore with a strong solution of caustic alkali to extract a further amount of zinc from the ore, and adding to the liquor thereby produced an acid in amount at least nearly equivalent to the alkali present in said solution, to precipitate lead therefrom. 8 claims.

—Described. Jour. Soc. Chem. Ind. vol. 35. p. 744. July 15, 1916.

601 1,185,757. Process of preparing pure zinc sulphate solution from zinc ores.—**Shunjiro Araki,** Osaka, Japan. Filed Sept. 6, 1913. Issued June 6, 1916.

The process of producing a pure zinc sulphate solution from zinc ores which comprises extracting the ores with a sodium bisulphate solution, removing from the solution the heavier metals by treatment with metallic zinc, separating the greater part of the iron and manganese by neutralizing with alkali and by treatment with an oxidizing agent, and removing the remainder of the iron and manganese by adding sodium silicate neutralizing the sodium silicate with sulphuric acid to form silicic acid and sodium sulphate and heating the resulting solution containing silicic acid to convert the dissolved colloidal silicic acid into an insoluble form. Patented also in England, no. 15,546 of 1913; in France, no. 464,038; in Germany, no. 273,609. See also item 496.

602 1,185,902. Process of treating ores.—**Royal S. Handy,** Kellogg, Idaho. Filed October 28, 1914. Issued June 6, 1916.

The process of treating sulphide ores containing lead, silver and zinc which comprises roasting the ore, extracting the lead sulphate with an aqueous solution of sodium chloride then extracting the silver and zinc with an aqueous solution of ferric chloride, and recovering the metal values from the resulting solutions.

603 1,198,241. Treatment of zinc solutions for the recovery of the metal therefrom.—**Robert Lance,** Paris, France. Filed June 24, 1914. Issued September 12, 1916.

The process of treating solutions containing sulphate of zinc, consisting in maintaining the zinc solutions saturated with sulphurous acid while adding gradually to the zinc solution during the treatment with sulphurous acid, earthy alkaline oxide whereby the zinc sulphite formed is maintained in solution. Patented also in France, no. 463,614.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 1068. Oct. 31, 1916.

604 1,201,586. Process for the production of zinc oxide.—**Edouard Hunebelle**, Paris, France. Filed May 23, 1914. Issued Oct. 17, 1916.

The method of obtaining pure zinc compounds from zinciferous materials, which consists in treating the zinciferous material with hydrochloric acid and then adding magnesium sulphate and calcium carbonate to precipitate impurities and leave substantially pure zinc chloride.

605 1,204,843. Process of extracting metals from their ores.—**S. E. Bretherton** and **F. L. Wilson**, Berkeley, Cal. Issued Nov. 14, 1916.

To extract zinc from zinc sulphide ores, the ore is pulverized, roasted to convert the zinc into basic sulphate, treated under pressure with a solution containing ammonia and carbon dioxide to dissolve the zinc, and the solution separated and heated to precipitate the zinc as a basic carbonate.

606 1,261,694. Method of treating sulphide ores.—**Frank K. Cameron** and **John A. Cullen**, Salt Lake City, Utah, and **Reed W. Hyde**, New York, N. Y., assignors to American Smelting and Refining Company, Salt Lake City. Filed June 18, 1917. Issued April 2, 1918.

The method of recovering elemental sulphur and metal values from sulphide ores, which consists in quickly heating sulphide ore and strong sulphuric acid to a reacting temperature approximating the boiling point of the acid, distilling off sulphur, and recovering the metal values from the residue.

607 1,261,695. Production of zinc chloride.—**Frank K. Cameron** and **John A. Cullen**, Salt Lake City, Utah, and **Reed W. Hyde**, New York, N. Y., assignors to American Smelting & Refining Company, Salt Lake City. Filed June 18, 1917. Issued April 2, 1918.

Method of preparing zinc chloride from oxide ores of zinc, which consists in reacting thereon with strong solution of hydrochloric acid in proportions sufficient to combine with the bases present, dessicating the mass by heat and maintaining the same at about 300° C. until substantial evolution of hydrochloric acid ceases and then dissolving the zinc chloride from the mass.

—Described in Met. & Chem. Eng. vol. 18, p. 550. May 15, 1918.

608 1,261,696. Producing zinc chloride from ores.—**Frank K. Cameron** and **John A. Cullen**, Salt Lake City, Utah, and **Reed W. Hyde**, New York, N. Y., assignors to American Smelting & Refining Company, Salt Lake City. Filed July 17, 1917. Issued April 2, 1918.

Method of producing zinc chloride from oxidized zinc ores also containing lead, which consists in mixing the ore with a metal chloride, distilling lead chloride from the mixture, and recoverong the zinc chloride from the distillation residue by leaching.

608a 1,281,031. Process of recovering zinc.—**Frederick Laist**, Anaconda, Mont., assignor to Anaconda Copper Mining Company. Filed Jan. 29, 1918. Issued October 8, 1918.

In a process of recovering zinc from silicious calcine, the steps which consist in leaching the calcine with an acid liquor, neutralizing the liquor and thereby precipitating silica in presence of the insoluble residue, separating the zinc bearing solution from the residue, dehydrating the residue, recovering zinc values therefrom by leaching with an acid solution and returning the resulting zinc bearing solution to the primary leaching operation.

608b 1,295,080. Extraction of zinc.—**Henry Livingstone Sulman** and **Hugh F. Kirkpatrick-Picard**, London, England, assignors to The Metals Extraction Corporation, Ltd. Filed Jan. 20, 1917. Issued Feb. 18, 1919.

In a process for the extraction of zinc from zinc-containing material treating the material with acid to dissolve the zinc, filtering the clear solutions from the residue, washing the residue to remove the solution remaining therein, adding milk of lime to the said washings to precipitate zinc hydrate and adding the precipitate so obtained to the solution produced from a fresh batch of zinc-containing material by treatment with acid to complete quickly the neutralization of the acid.

Part of a process preparatory to electrolysis.

Great Britain

609 1,374 of 1891. Treating ores and residues containing zinc by means of bisulphate of soda for the production of commercial products—**A. M. Clark**, London.

610 4,916 of 1894. Treating zinc and iron chloride.—**E. Warzee**, Brussels.

Separating zinc and iron chlorides by adding sufficient metallic zinc to the solution to throw down all the iron as oxide.

611 13,850 of 1894. Improved process of treating refractory ores and apparatus to be used therein. **E. A. Ashcroft**, Broken Hill, N. S. W.

The ore is given an oxidizing roast, leached by the ferric chloride or ferric sulphate method, according to relative zinc-lead content, and electrolyzed with insoluble anodes. Many modifications of the process are described in the patent claims.

612 22,826 and 22,827 of 1894. Improvements in the treatment of zinc chloride for the purification thereof for electrolytic processes.—**J. Brock, A. E. Wareing** and **F. Hurter,** Liverpool.

Removing oxides and sulphides of zinc and other impurities from zinc chloride solution before electrolysis.

613 7,560 of 1895. Leaching zinc.—**Carl Hoepfner,** Giessen, Germany.

In the process of producing chloride of zinc from sulphide, mixing nitric acid with the acid and the ore, so as to prevent the oxidation of the sulphide.

614 8,328 of 1895. Treating zinc-lead sulphides.—**C. Hoepfner,** Giessen, Germany.

Treating zinc lead sulphides with chlorine or chlorides of iron or copper, so dissolving out the lead and leaving the zinc.

—Described in Zeits. f. Elektrochem., vol. 3, p. 109. Sept. 5, 1896.

615 8,449 of 1895. Making zinc chloride.—**C. Hoepfner,** Giessen, Germany.

Making zinc chloride by treating zinc oxide with sulphurous acid, oxidizing to sulphate and treating with an alkaline chloride.

.616 8,328 of 1896. Improvements in the treatment of ores or materials containing zinc, lead, and silver.—**C. Hoepfner,** Giessen, Germany.

Treated with a chloride solution to remove lead and silver. The residue containing zinc may be treated for its recovery in any known way.

617 10,494 of 1896. Recovery of zinc.—**J. R. Wylde, J. W. Kynaston** and **J. Brock,** Liverpool.

Method of recovering zinc from the spent liquors or copper leaching.

618 16,312 of 1896. Treatment of solutions of ores containing zinc for the recovery of zinc as oxide.—**E. A. Ashcroft,** New Castle, N. S. W.

"Zinc sulphate is converted into a paste by stirring in zinc oxide, which is strongly heated so as to drive off sulphuric or sulphurous acid gases. In some cases the pasty mass is mixed with carbon before heating."—J. S. C. I.

619 17,299 of 1896. Improved process for the treatment of zinciferous sulphide ores.—**E. F. Turner,** Adelaide, Australia.

The crushed ore is roasted to oxide in the presence of a current of superheated steam. The zinc and lead oxides are converted into sulphites.

—Described in Jour. Soc. Chem. Ind., vol. 16, p. 683, Aug. 31, 1897.

620 20,615 of 1896. Treatment of zinc and copper ores.—**W. J. Koehler,** Broken Hill, N. S. W.

Zinc and copper being present as oxides, the ore is leached with ammonium sulphate and heated to 300° -500° C.

621 9,409 of 1897. Reducing zinc-lead sulphides.—**H. R. Angel,** London.

Improvements in the process for reducing zinc-lead sulphides by sulphate of soda.

622 16,808 of 1897. Treatment of complex sulphide ores and apparatus therefor.—**F. Ellershausen,** London.

—Described in Jour, Soc. Chem. Ind., vol. 16, p. 1021, Dec. 31, 1897.

623 285 of 1898. Improvements in the treatment of ores containing intimately mixed copper, lead and zinc.—**Guy de Bechi,** Paris.

"The crushed ores are given a chlorinating roasting, followed by practical precipitation of the copper and zinc as hydrated oxides."

624 11,940 of 1898. Improved method of treating flue dust obtained from sulphide ores.—**R. Threlfall,** Preston.

"The flue dust and fume are treated with a solution of potassium or sodium hydrogen sulphate, such as nitre-cake, by which the zinc is dissolved and separated from the lead."

.625 22,366 of 1898. Production of zinc oxide and carbonate from ores or other materials containing zinc.—**G. Rigg,** Swansea.

" The material is leached with a solution of ammonium carbonate or a mixture of this with ammonium hydrate. The zinc-dissolving capacity of the solution varies with the amount of carbonic acid present. The zinc is precipitated by means of carbonic acid gas."—J. S. C. I.

626 2,712 of 1899. Treatment of refractory sulphide ores.—**W. R. Hutton,** Glasgow.

"The ores are heated with nitrate of soda, which may be added as a dry salt to the ore in the furnace, or as a concentrated solution to the ore previously. The metals are converted into their sulphates, and the fumes are forced into water, the zinc sulphate dissolving and the lead sulphate remaining insoluble,"—J. S. C. I

627 3,575 of 1899. Sulphide ore treatment.—**Chemische-Fabrik Rhenania,** Aix-La-Chapelle, Germany.

Treating mixed sulphide ores ground fine with concentrated sulphuric acid under heat, so forming sulphates of lead and zinc separable by lixiviation.

628 10,850 of 1899. Extraction of zinc from substances or compounds containing the same.—**T. Ryan,** jr. and **N. Hughes,** Flint.

Zinc fume, flue dust, calcined blende, waste scrap or like material is treated with solution of caustic alkali; any lead is precipitated with zinc and iron scrap; the zinc is precipitated as oxide by means of carbonic acid.

629 21,871 of 1899. Obtaining zinc solutions free from iron and manganese compounds.—**F. A. Gasch**, Hoemmingen-am-Rhein, Germany.

"Zinciferous spent pyrites is treated with concentrated H_2SO_4, with or without the addition of sodium chloride, or with strong HCl and $FeCl_2$, and after remaining in heaps for a time, the mass is roasted at a low red heat. After withdrawal from the furnace, but while still nearly red hot, sodium nitrate or other oxydizing agent and lime are added. The ferrous and manganese compounds are thus oxidized and remain undissolved on leaching, a zinc solution being obtained."—J. S. C. I.

630 253 of 1900. Improved process for separating lead from zinc, when both metals exist together in solution as nitrates, chlorides, or partly as nitrates and partly as chlorides.—**G. E.** and **A. R. Davis**, Manchester.

"Zinc oxide is added to the solution of mixed lead and zinc salts, and carbonic acid gas is passed through, whereby lead carbonate is precipitated, zinc replacing lead in the solution."—J. S. C. I.

631 710 of 1900. Treatment of certain mixed sulphide ores for the recovery of their valuable constituents.—**G. E.** and **A. R. Davis**, Manchester.

"Treating mixed sulphides of lead and zinc by leaching with nitric acid and removing the lead by adding zinc oxide."—E. & M. J.

632 985 of 1900. Treatment of complex zinc ores.—**Guy de Bechi**, Paris.

"Zinc-bearing sulphide ores are mixed and roasted with 15 to 30% of silica, silicious sand, or other silicious matter, whereby the zinc is rendered more completely soluble in acid than when the ore is roasted by itself, and consequently the residue, after leaching, is more suitable for further metallurgical treatment."—J. S. C. I.

633 2,089 of 1900. Treatment of mixed sulphide ores containing lead and zinc.—**G. E.** and **A. R. Davis**, Manchester.

"Improvements in the patentees' process (253 and 710 of 1900) for treating mixed zinc-lead sulphides by lixiviation with hydrochloric acid and adding zinc oxide to precipitate the lead."—E & M. J.

—Described in Jour. Soc. Chem. Ind., vol. 19, pp. 129-130, Feb. 28, 1901.

634 11,108 of 1900. Zinc sulphide pigment.—**E. Beringer**, Berlin, Germany.

The production of zinc sulphide suitable as white pigment from an ammoniacal solution of zinc oxide.

635 14,983 of 1900. Treatment of zinc-lead sulphide ores and tailings.—**T. Twynam**, London.

Treating with chloride of zinc and separating out the lead chloride.

—Described in Jour. Soc. Chem. Ind., vol. 20, p. 905, Sept. 30, 1901.

636 12,510 of 1901. Zinc sulphate making.—**Meister Lucius & Bruning,** Hoechst-am-Main, Germany.

Method of making a sparingly soluble zinc hydrosulphite by treating a sulphite with zinc dust and an acid.

637 21,097 of 1901. Extraction and recovery of zinc from sulphide ores or tailings.—**C. Rogers & A. M. Oswald,** Caulfield, Australia.

Calcium polysulphide is claimed for use in precipitating zinc sulphide from sulphate solutions.

638 16,272 of 1902. Treating zinc slags.—**F. Brunjes,** Langelsheim, A. M., Germany.

Treating copper slags containing zinc, barium, iron, etc., with HCl, the iron, barium, etc., being dissolved and the zinc recovered as sulphide.

639 9,360 of 1903. Making zinc hydrosulphite.—**C. Bolle,** Manchester.

An improved process for making zinc hydrosulphite difficultly soluble in water by acting on zinc dust with sulphurous acid and then adding sodium bisulphite.

640 23,843 of 1903. Leaching sulphide ores.—**J. B. de Alzugaray,** London.

Leaching sulphides by means of solutions of chlorides or alkali and other metals, with free hydrochloric acid.

641 13,121 of 1904. Recovery of zinc.—**J. Nicholas,** Liverpool.

"Removing zinc from mixed ores by roasting with salt and dissolving out the chloride of zinc, and afterward collecting silver and gold from the lead by means of aluminum."—E. & M. J.

642 15,577 of 1904. Leaching sulphide ores.—**J. Nicholas,** Liverpool.

"Treating complex ores with common salt, and then leaching out the zinc chloride, and afterward adding more salt, sulphuric acid and peroxide of manganese for the purpose of converting the remaining metals into chlorides."--E. & M. J.

643 22,235 of 1905. Leaching ores.—**H. Baker** and **A. T. Smith,** Runcorn, England.

"Treating finely ground sulphides of lead, zinc etc., with aqueous solutions of ferric chloride, thus forming chloride of the metal, ferrous chloride, and free sulphur."— E. & M. J.

644 24,238 of 1905. Method of treating complex sulphide ores containing copper, zinc and lead.—**N. M. Ogle,** London.

"The granular ore is roasted at a dull red heat so as to convert as much as possible of the zinc sulphide into sulphate: to this end, a small quantity of sodium nitrate may be added. The roasted ore is systematically extracted with boiling water, which dissolves out zinc sulphate. The impure zinc sulphate solution is freed from copper either by electrolysis or by adding metallic zinc, and from iron by oxidizing the solution by air or bleaching powder and adding zinc oxide or carbonate, and is evaporated to dryness.. .. .. zinc oxide is formed," purified, briquetted and smelted for zinc.—J. S. C. I.

—Described in Jour. Soc. Chem. Ind. vol. 26, p. 21, Jan. 15, 1907.

645 16,912 of 1906. Leaching ores.—**R. W. E. MacIvor** and **M. Fradd,** London.

"Improvements in the method of dissolving zinc from roasted zinc-lead ores by means of calcium chloride or sulphurous acid, and subsequently precipitating by lime."—E. & M. J.

646 17,001 of 1906. Treatment of zinc.—**R. W. E. MacIvor** and **M. Fradd,** London.

Treating residues from zinc distilling furnaces by mixing with sulphuric acid into a stiff paste and heating to about 300° to 500° C., and then leaching out the sulphate of zinc so formed.

647 21,440 of 1906. Extracting zinc from residues.—**R. W. E. MacIvor** and **M. Fradd,** London.

"Extracting zinc from distillation residues by heating with calcium chloride and sulphuric acid and throwing down the oxide from the resulting zinc chloride solution by the addition of lime."—E. & M. J.

648 22,534 of 1906. Ore treatment.—**H. L. Sulman,** London.

"Improvement in the process described in 21,672 of 1906, whereby the zinc is precipitated as monosulphite by blowing air through the solution of bisulphite."—E. & M. J.

649 24,526 of 1906. Treatment of calamine.—**F. S. Mojano,** Aguilas, Spain.

"Process for utilizing low grade calamine by first calcining and then treating with a solution of calcium chloride, the zinc chloride thus produced being precipitated as oxide by the admixture of carbonate and magnesium."—E. & M. J.

650 26,934 of 1906. Treatment of sulphide ores.—**H. Baker,** Runcorn, England.

"Improvements in the inventor's process for treating sulphide ores with chlorides for the production of lead, copper or zinc chlorides with the object of preventing the undue precipitation of these metals from the solutions obtained."—E. & M. J.

651 4,471 of 1909. Method of recovering lead and zinc from compounds containing these metals.—**H. W. Hemenway,** Stratford, Essex.

Comprises treatment "with lead or zinc acetate or with acetic acid, so that the lead goes into solution as subacetate, while the zinc is precipitated."—J. S. C. I.

652 18,817 of 1909. Bisulphite process.—**W. Hommel** and **H. T. Durant.**

—Described in Min. Mag., vol. 4, p. 139, Feb., 1911.

653 17,587 of 1910. Method of extracting oxide of zinc from ores and tailings.—**F. C. Beauchamp,** London.

"The ore is first treated with sulphuric acid to dissolve the metals which are precipitated as hyroxides by means of lime. Treatment with sodium hydroxide or ammonia separates the zinc in solution. Addition of sulphuric acid or zinc sulphate solution re-precipitates the zinc as hydroxide, which is washed and heated to yield the oxide."

654 16,218 of 1912. Removal of zinc from the ore, particularly of zinc-lead ore.—**H. C. Woltereck** and **J. Moeller,** London. Issued July 11, 1912.

"Process of removing zinc from roasted ores by means of hot ferrous sulphate solution, zinc sulphate and ferrous hydroxide being formed."—J. S. C. I.

655 12,799 of 1915. Extraction of zinc.—**Metals Recovery Co., Ltd.** and **R. W. E. Mac Ivor,** London.

This process is applicable to lead-zinc sulphide ores containing iron. The ore is given a sulphating roast, mixed with a certain proportion of a previous charge containing ferric oxide. The roasted ore is then leached in sulphuric acid solution.

—Described in Min. Mag., vol. 16, p. 55. Jan., 1917.

France

656 392,867. Treatment of acid metallic solutions for the extraction of zinc.—**P. D'Alton-Shee.** Oct. 8, 1907.

Applicable to separation of zinc from other metals in a solution "such as that obtained by the action of acid on roasted blende. The filtered solution is mixed with a small quantity of sodium hydrochlorite, in order to oxidize any iron, chromium or manganese, which are afterwards precipitated by the addition of zinc oxide or hydroxide to the hot solution. The zinc is finally precipitated by the addition of ammonia, not in excess."—J. S. C. I.

657 408,062, 408,092 and 408,093. Process, lixiviation apparatus, and reduction furnace for the treatment of zinc carbonate ores.—**G. Dantin.** Oct. 16, 1909.

The ore is treated with sulphurous acid at a temperature above 50°C., whereby the zinc carbonate is converted into sulphate, which is recovered by lixiviation.

—Described in Jour. Soc. Chem. Ind., vol. 29, p. 637. May 31, 1910.

658 476,304. Process for treating ores of zinc, copper, cadmium, cobalt, nickel, etc.—**R. D. Lance.** Apr. 15, 1914.

The metals are converted into sulphates by heating the ore with sulphuric acid, the product is roasted at about 800° C. in presence of air and steam to decompose ferric sulphate, and the sulphates are removed by leaching and converted into chlorides by addition of calcium chloride. The metals are precipitated from the chloride solution as hydroxides by adding calcium sodium oxychloride, with regeneration of calcium chloride.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 54. Jan. 15, 1916.

659 480,499. Production of zinc sulphate from zinciferous minerals.—**Erminio Ferraris.** Dec. 21, 1915.

The roasted or desulphurized ore is treated with sulphur dioxide, and the precipitated zinc sulphite is treated with moist air to convert it into sulphate, which is dissolved by lixiviation with pure or acidulated water.

Germany

660 86,153. Zinc leaching.—**C. Hoepfner,** 1895.

Process for transforming the zinc oxide formed by roasting calamine or blende into a carbonate, preliminary to converting the carbonate into chloride as in English Patent 11,724 of 1894.

661 142,933. Dezincing zinciferous roasted pyrites.—**August Gasch,** Munich. Sept. 21, 1899.

Leaching with concentrated sulphuric acid, and roasting.

—Described in Zeits. f. angewandte Chem., vol. 16, p. 684. July 14, 1903.

662 149,161. Process for climinting pyritic iron from zinc blende.—**Alfred Kunze** and **Karl Danziger,** Zawodzie, Silesia, Germany. Feb. 22, 1903.

The ore is given an oxidizing roast, to make the pyrites soluble in water.

—Described in Zeits. f. angewandte Chem., vol. 17, p. 430. Apr. 1, 1904.

663 154,085. Process for eliminating the iron and manganese from zinc solutions.—**Lorenz Lucas,** Hagen, Germany. Nov. 1, 1903.

Treatment with lead peroxide.

—Described in Zeits. f. angewandte Chem., vol. 17, p. 1829. Nov. 25, 1904.

664 165,455. Process for working up zinciferous ores and smelter products.—**Zinkgewinnungs-Gesellschaft,** Berlin. Mar. 24, 1905.

Leaching with sulphuric acid and precipitation of the zinc as hydroxide, by means of sodium hydroxide. Modified by 169,138, below.

—Described in Zeits. f. angewandte Chem., vol. 19, p. 1619. Sept. 21, 1906.

—Described in Jour. Soc. Chem. Ind., vol. 25, p. 991. Oct. 31, 1906.

665 169,138. Process for the treatment of zinciferous ores and smelter products.—**Zinkgewinnungs-Gesellschaft,** Berlin. May 24, 1905.

Addition to 165,455, above. "Zinc and magnesium hydroxides are precipitated by quick-lime, and the zinc is dissolved out of the precipitate by treatment with a solution of sodium hydroxide and sodium sulphate. The solution is used for leaching a fresh quantity of ore."

—Described in Jour. Soc. Chem. Ind., vol. 25, p. 991. Oct. 31, 1906.

666 170,460. Process for producing a pure zinc chloride solution from waste liquors containing organic impurities.—**T. Goldschmidt,** Essen, Germany. June 8, 1906.

The solution is heated to 300° or 400°.

667 173,209. Process for recovery of zinc from siliceous zinc ores by leaching with a concentrated neutral zinc salt solution.—**Alfred V. Cunnington,** Winnington, England. Jan. 28, 1904.

—Described in Zeits. f. angewandte Chem., vol. 20, p. 159. Jan. 25, 1907.

668 188,793. Process for the recovery of copper, zinc, cadmium, etc., from their carbonate or oxide ores in the form of hydroxides.—**Denis Lance,** Paris. Mar. 29, 1905.

—Described in Zeits. f. angewandte Chem., vol. 21, p. 166 Jan. 24, 1908.

669 197,044. Process for leaching zinc and other metals from oxidized or roasted ores by means of sulphuric acid and ferric sulphate.—**William G. Rumbold** and **George Patchin,** London. Feb. 7, 1906.

—Described in Zeits. f. angewandte Chem., vol. 21, pp. 1460-61. July 3, 1908.

670 200,613. Process for working up mixed sulphide ores with ferric sulphate, oxidizing the resulting ferrous sulphate, and using in the process the acid gas generated by the calcination of the zinc sulphate.—**Guido de Bechi** and **Reginald W. Ruecker,** London. Apr. 19, 1907.

—Described in Zeits. f. angewandte Chem., vol. 21, p. 1992. Sept. 18, 1908.

671 203,149. Process for dezincing zinc and iron bearing materials by heating with concentrated sulphuric acid and subsequent leaching.—**Zinkgewinnungs-Gesellschaft,** Berlin. Feb. 21, 1907.

—Described in Zeits. f. angewandte Chem., vol. 22, p. 268. Feb. 5, 1909.

—Described in Jour. Soc. Chem. Ind., vol. 27, p. 1158. Dec. 15, 1908.

672 203,628. Process for the manufacture of zinc oxide by the leaching of ores with sulphurous acid.—**Henry L. Sulman,** London. Oct. 21, 1906.
—Described in Zeits. f. angewandte Chem., vol. 22, p. 270. Feb. 5, 1909.

673 209,508. Process for the extraction of copper, zinc and other metals, except gold, from roasted pyrite residues.—**Auguste Tixier,** Billancourt, France. Aug. 26, 1906.
Leaching with chlorine.
—Described in Zeits. f. angewandte Chem., vol. 22, p. 1035. May 28, 1909.

674 218,226. Process for working up refractory lead ores by treatment with ammonium sulphate or ammonium chloride.—**P. C. C. Isherwood,** Wealdstone, England. July 19, 1907.

675 246,047. Process for working up siliceous zinc ores, by which the zinc is sulphatized without perceptibly sulphatizing the lead, and simultaneously a concentrated solution of zinc sulphate is obtained.—**Frank B. Dick,** Lyndhurst, England. July 11, 1911.
—Described in Zeits. f. angewandte Chem., vol. 25, pp. 1257-58. June 14, 1912.

676 246,973. Treatment of mixed lead-zinc ores for the purpose of recovering lead and a pure zinc solution.--**Jean de Coppet,** Paris, France. Aug. 27, 1910.
—Described in Zeits. f. angewandte Chem., vol. 25, p. 1258. June 14, 1912.

677 254,443. Treatment of materials containing zinc or zinc oxide with a zinc chloride solution.—**Georg Wannschaff** and**Josef Savelsberg,** Papenburg, Germany. Mar. 8, 1910.
—Described in Zeits. f. angewandte Chem., vol. 26, pt. II, p. 55. Jan. 28, 1913.

678 257,647. Precipitation of metals, especially of zinc, copper or nickel, from sulphuric or sulphurous acid solutions by means of magnesium compounds, such as magnesium sulphite or bicarbonate.—**Stanislaw Laszczynsk',** Miedzianka, Russia. Nov. 20, 1910.

679 266,219. Process for the technical separation of lead and zinc which are present in ore as sulphides, by means of a ferric sulphate solution containing sulphuric and nitric acid.—**Guido de Bechi,** London. Mar. 12, 1913.
—Described in Zeits. f. angewandte Chem., vol. 26, pt. II, p. 687. Nov. 18, 1913.

680 271,135. Production of metallic zinc and zinc white—**Pierre Ferrere,** Paris, France. Mar. 7, 1912.

The zinc in the ore to be treated is made water-soluble by a chloridizing or sulphatizing roast; the zinc chloride or sulphate freed from the other metals present, and then treated with lime and sulphurous acid, the lime being in the form of calcium bisulphite, which, in presence of excess of sulphurous acid, is immediately disintegrated through the zinc sulphate or chloride.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 261. Apr. 17, 1914.

681 271,136. Recovery of pure zinc oxide from impure oxides which contain also lead oxide.—**Heinrich Heimann,** Berlin. Nov. 14, 1912.

The lead oxide is separated by leaching with caustic potash and electrolyzing.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, pp. 261-62. Apr. 17, 1914.

682 271,658. Process for recovering zinc from calamine, especially from ores of low zinc content, as also from smelter residues, by leaching with ammonia.—**Jozef Jerzy Boguski,** Warsaw, and **Aktien-Gesellschaft fuer Bergbau und Huettenbetrieb.** Feb. 23, 1912.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, pp. 257-58. Apr. 17, 1914.

683 273,064. Production of an iron-free zinc solution from solutions containing iron oxide.—**Wilhelm Buddeus,** Charlottenburg, Germany. Dec. 12, 1912.

684 275,308. Treatment of sulphide ores or metal-bearing solutions for the recovery of zinc.—**Edgar A. Ashcroft,** Sogn, Norway. Apr. 25, 1912.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 444. July 17, 1914.

685 278,621. Process for the treatment of sulphide ores for the production of metallic zinc.—**Edgar A. Ashcroft,** Sogn, Norway.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 632. Nov. 13, 1914.

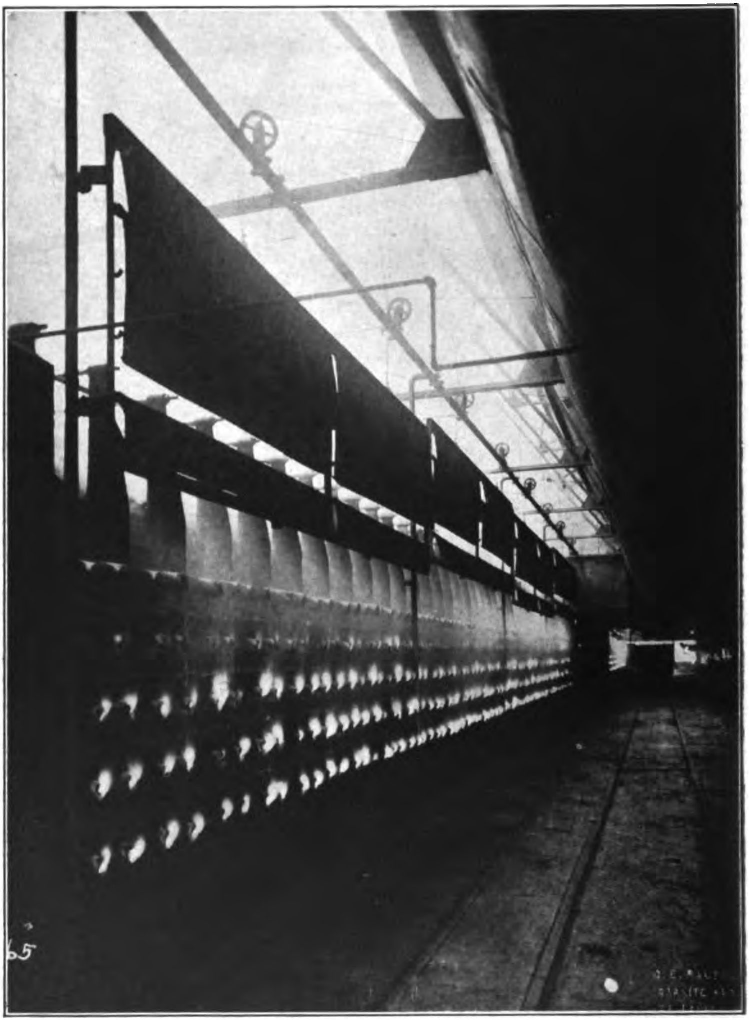
686 284,982. Process for the treatment of zinciferous ores with sulphurous acid.—**Erzverwertungs-Gesellschaft m. b. H.** Apr. 25, 1913.

Bisulphite process.

—Described in Jour. Soc. Chem. Ind., vol. 34, p. 1100. Nov. 15, 1915.

687 285,617. Process for the recovery of pure zinc oxide or pure metallic zinc by treating a purified solution of zinc salts with ammonium sulphite, regenerating the spent ammonium sulphite, and calcining the resulting zinc sulphite.—**Henry William, baron de Stuckle,** Lieuze, Lorraine. Dec. 8, 1912.
—Described in Zeits. f. angewandte Chem., vol. 28, pt. II, p. 435. Aug. 20, 1915.

687a 304,937. Process for the recovery of zinc from waste liquors containing zinc and sodium sulphates.—**Otto Bimpage,** Duisburg-am-Rhein. April 11, 1918.
—Abstract. Zeits. f. angewandte Chem., vol. 31, p. 138. May 10, 1918.



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688 Die amerikanische Zinkindustrie in bezug auf den Charakter der den Huetten eingelieferten Zinkerze.—**W. R. Ingalls.** Metallurgie, vol. 1, pp. 377-81. Sept. 22, 1904.

689 Aus der Metallurgie des Zinks.—**Franz Juretzka.** diagr. Metall u. Erz, vol. 12, pp. 63-69, 94-102. Feb. 22, Mar. 8, 1915.

Discusses ore-dressing, wet chemical treatment, pyro-chemical treatment, muffles, and smelting, suggests partial reduction of zinc in the muffle, then roasting with coke; CO gas is formed, burned with air and used to heat the muffles. Zinc oxide is condensed in the dust chambers.

690 Beitraege zur Metallurgie des Zinks.—**H. Brandhorst.** diagr. Zeits. f. angewandte Chem., vol. 17, pp. 505-17. Apr. 15, 1904.

Details and problems arising in smelting, with especial reference to Silesian practice. The last three pages are on electrolytic methods.

—Abstract. Jour. Soc. Chem. Ind., vol. 23, p. 491. May 16, 1904.

691 Beitraege zur Chemie des Zinkhuettenprozesses.—**Viktor Lepiarczyk.** Metallurgie, vol. 6, pp. 409-19. July 8, 1909.

A discussion of various chemical problems and difficulties involved in roasting and smelting. Presence of iron in the blende causes the roasting to be incomplete. Lime causes losses of sulphur by formation of calcium sulphate. See also item 770.

—Abstract: Contributions to the chemistry of zinc smelting. Jour. Soc. Chem. Ind., vol. 28, pp. 838-39. Aug. 16, 1909.

—Same abstract. Eng. & Min. Jour., vol. 88, p. 604. Sept. 25, 1909.

—Abstract: Chemistry of zinc smelting. Min. Jour., vol. 86, p. 326. Sept. 4, 1909.

—Abstract: Metallurgical chemistry of zinc. Min. Mag., vol. 1, p. 322. Dec., 1909.

—Abstract: Chemistry of smelting. Min. Sci., vol. 60, p. 85. Dec. 23, 1909.

—Abstract: Roasting of zinc ores. Jour. Inst. Metals, vol. 2, pp. 295, 321. 1909.

—Abstract: Chemistry of zinc smelting. Mex. Min. Jour., vol. 9, no. 6, p. 26. Dec., 1909.

—Abstract: Zinc smelting. Mex. Min. Jour., vol. 12, no. 6, p. 18. June, 1911.

—Same abstract, in Spanish. Mex. Min. Jour., vol. 12, no. 4, pp. 52-53. April, 1911.

—Abstract: Effect of impurities on roasting and distillation process. Met. & Chem. Eng., vol. 8, pp. 44-45. Jan., 1910.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 22, p. 1943. Oct. 1, 1909.

692 Beitrag zur Metallurgie des Zinkes.—**Paul Schmieder.** diagr. Metallurgie, vol. 2, pp. 20-26. Jan. 8, 1905.

Methods and chemistry of the smelting process. See also criticism by Schuchard, item 850.

—Abstract. Zeits. f. angewandte Chem., vol. 18, p. 1326. Aug. 18, 1905.

693 Beitrag zur Verarbeitung von Blenden mit kalkhaltiger Gangart.—**L. Bisschopinck.** Metallurgie, vol. 3, pp. 726-27. Nov. 8, 1906.

Presence of $CaSO_4$ is not the reason for difficulty in smelting, but "lack of sufficient heat, which may be due to too low a temperature in the muffle, to too short a period of reduction, or both." Experience at the Godullahuette, Upper Silesia.

—Abstract: Smelting blende containing calcareous gangue. Eng. & Min. Jour., vol. 82, p. 1216. Dec. 29, 1906.

—Abstract: Working up of blendes with calcareous gangue. Jour. Soc. Chem. Ind., vol. 26, p. 51. Jan. 31, 1907.

694 Betrachtungen ueber die Waermebilanz eines Siemens-Zinkofens.—**F. Eulenstein.** diagr. Metallurgie, vol. 9, pp. 328-34, 353-62, 396-403. May 22, June 8, 22, 1912.

"A remarkably competent and painstaking study of the heat balance of a Siemens zinc distillation furnace."

—Abstract. Mineral Industry, vol. 21, p. 893. 1912.

695 Blendische Bleiglanze. Metallurgie, vol. 1, p. 89. Mar. 8, 1904.

Miller's English Patent 20,465 of 1902. Separation of zinc and lead in distillation. Experiments on Broken Hill ores.

696 Cadmium recovery in zinc smelting.—**D. M. Liddell.** Mineral Industry, vol. 19, pp. 91-92. 1910.

697 Calculation of the latent heat of vaporization of zinc.—**Woolsey McA. Johnson.** Amer. Electrochem. Soc., Trans., vol. 14, pp. 251-53. 1908.

Calculation by use of thermodynamics, "422 calories is a close enough figure for practical purposes."

—Abstract: Vaporization of zinc. Electrochem. & Met. Ind., vol. 6, p. 495. Dec., 1908.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 22, p. 205. Jan. 29, 1909.

698 The chemical and physical reactions in a zinc retort.—**F. L. Clerc.** Met. & Chem. Eng., vol. 10, pp. 399-401. July, 1912.

699 Complex zinc ores. Min. Mag., vol. 10, pp. 408-9. June, 1914.

700 Controlling the formation of zinc dust in smelting. Met. & Chem. Eng., vol. 12, pp. 530-31. Aug., 1914.

Alex Roitzheim's Patent 1,100,490 Preheating the smelting charge to a temperature of about 600° C. before placing it in the retort.

701 Development of zinc smelting in the United States.—**George C. Stone.** Met. & Chem. Eng., vol. 13, pp. 726-27. Oct. 15, 1915.

Historical review describing a number of processes. Abstract of a paper at the International Engineering Congress, San Francisco, September, 1915.

702 Distillation process with internal heating. diagr. Electrochem. & Met. Ind., vol. 4, pp. 461-62. Nov., 1906.

H. Mehner's Patent 833,472.

703 Distillation without retorts. Electrochem. & Met. Ind., vol. 4, pp. 371-72. Sept., 1906.

Armstrong's Patent 830,293.

704 A dry process for the treatment of complex sulphide ores. **H. L. Sulman** and **H. F. Kirkpatrick-Picard.** Inst. Min. & Met., Trans., vol. 10, pp. 430-56. 1902.

Work on Broken Hill ores; gives costs.

—Abstract. Eng. & Min. Jour., vol. 74, pp. 112-13. July 26, 1902.

—Abstract. Jour. Soc. Chem. Ind., vol. 21, p. 975. July 31, 1902.

—Abstract. Mineral Industry, vol. 11, pp. 612-13. 1902.

705 Du Role du sulfate de calcium et du sulfate de baryum dans la reduction des minerais de zinc.—**Eugene Prost** and **Maurice Ubaghs.** Bull. Soc. Chim. Belge., vol. 26, pp. 532-41. 1912.

Effect of calcium and barium sulphates in the reduction of zinc ores.

—Same, in French. Rev. Univ. des Mines, Nov., 1912.

—Abstract. Jour. Soc. Chem. Ind., vol. 32, p. 90. Jan. 31, 1913.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 26, pt. II, p. 249. Apr. 22, 1913.

706 Examination of the reactions occurring in the metallurgical treatment of blende.—**Eugene Prost.** Bull de l'Assoc. Belge des Chim., vol. 10, pp. 212-25, 246-63. 1896.

Reactions of iron oxide and zinc oxide; reducing action of carbon; other reactions. In French.

—Abstract. Jour. Soc. Chem. Ind., vol. 15, pp. 723, 813-14. Oct. 31, Nov. 30, 1896.

707 Die Fortschritte in oberschlessischen Zinkhuttenbetriebe.—**A. Rzehulka.** Oester. Zeits. f. Berg- u. Huettenw., vol. 54, pp. 133-37. 1906.

Advance in zinc smelting practice in Upper Silesia.

708 Gattierung und Destillation im Zinkhuettenbetriebe.—**Franz Juretzka.** diagr. Metallurgie, vol. 8, pp. 1-7. Jan. 8, 1911.

Mixing of ores and temperature control in smelting. Paper at the Conference of Rhenish and Belgian Zinc Smelters at Cologne, April, 1910.

—Abstract: Mixing and distilling zinc ores. Min. Wld., vol. 34, p. 347. Feb. 11, 1911.

—Abstract: Grading and distillation of zinc ores. Jour. Inst. Metals, vol. 5, p. 298. 1911.

709 Gattierung von Zinkblende und Galmei.—**Franz Juretzka.**. Metallurgie, vol. 4, pp. 84-90. Feb. 8, 1907.

"Discusses very briefly the historical aspect of zinc smelting practice, and gives in detail the present state of the art of reducing zinc from mixtures of calamine and blende; also discusses the principles which govern the composition of the mixtures to be smelted."—E. & M. J.

—Same. Zeits. f. angewandte Chem., vol. 20, pp. 750-54. May 3, 1907.

710 Die gegenwaertigen Aussichten der Verhuettung von [illegible]erzen in den Vereinigten Staaten.—**W. R. Ingalls.** [illegible]lurgie, vol. 1, pp. 329-34. Aug. 22, 1904.

American zinc smelting methods.

711 Gewinnung von metallischem Zink oder Zinksta[illegible] schwefelzinkhaltigen Materialen, z. B. Zinkblende[illegible]lurgie, vol. 9, pp. 490-91. Aug. 8, 1912.

Recovery of metallic zinc or zinc dust from sulphide [illegible] K. Friederich's German Patent 244,803.

712 Gewinnung von Rohzink aus zinkhaltigen Materialen mit Hilfe von Carbiden. Metallurgie, vol. 9, p. 460. July 22. 1912.

Van de Casteele's German Patent 242,842.

713 Gewinnung von Zink aus seinen oxydischen oder Schwefelerzen oder aus Gemischen von solchen. Metallurgie, vol. 7, pp. 344-45. June 8, 1910.

Imbert's German Patent 218,408, for production of zinc from its oxides or sulphides or from a mixture of both, using a solution of Fe_2O_3.

714 Gewinnung von Zink durch Destillation. Metallurgie, vol. 9, p. 493. Aug. 8, 1912.

Specketer's German Patent 245,681.

715 Gleichzeitige Gewinnung von Kupfer und Zink aus an Zink reichen Schwefelkupfererzen. Metallurgie, vol. 9, pp. 493-94. Aug. 8, 1912.

Simultaneous recovery of copper and zinc from copper sulphide ores rich in zinc. German Patent 245,847, by Societe Commerciale des Mines, Minerais, et Metaux, Paris.

716 Historical note on zinc smelting.—**Herbert C.** and **L. H. Hoover.** In their translation of **Agricola's** De Re Metallica, Book ix, footnote, pp. 408-10.

—Same. Eng. & Min. Jour., vol. 96, pp. 741-42. Oct. 18, 1913.

717 History of smelting in the Joplin district.—**Doss Brittain.** illus. Eng. & Min. Jour., vol. 84, pp. 861-67. Nov. 9, 1907.

718 Improvements in the metallurgy of zinc.—**George C. Stone.** Amer. Electrochem. Soc., Trans., vol. 25, pp. 161-68. 1914.

Discussion showing that improvements in zinc metallurgy have been as great as in the metallurgy of copper and iron.

—Same. Min. Wld., vol. 40, pp. 465-67. Mar. 7, 1914.

—Abstract: Improvements in the retort process. Met. & Chem. Eng., vol. 11, p. 677. Dec., 1913.

—Abstract: Belgian furnaces in zinc smelting. Min. & Sci. Press, vol. 107, pp. 931-32. Dec. 13, 1913.

719 Influence of temperature and pressure on the volatility of zinc and cadmium.—**T. K. Nair** and **T. Turner.** diagr., graphs. Jour. Chem. Soc., vol. 103, pp. 1534-43. 1913.

—Abstract. Jour. Soc. Chem. Ind., vol. 32, p. 914. Sept. 30, 1913.

—Same abstract. Eng. & Min. Jour., vol. 97, p. 182. Jan. 17, 1914.

—Abstract. Jour. Inst. Metals, vol. 9, p. 234. 1913.

720 Influence of the degree of desulphurising upon the yield of zinc from zinc blende.—**Eugene Prost.** Bull. de l'Assoc. Belge des Chim., vol. 14, pp. 125-31. 1900. In French.

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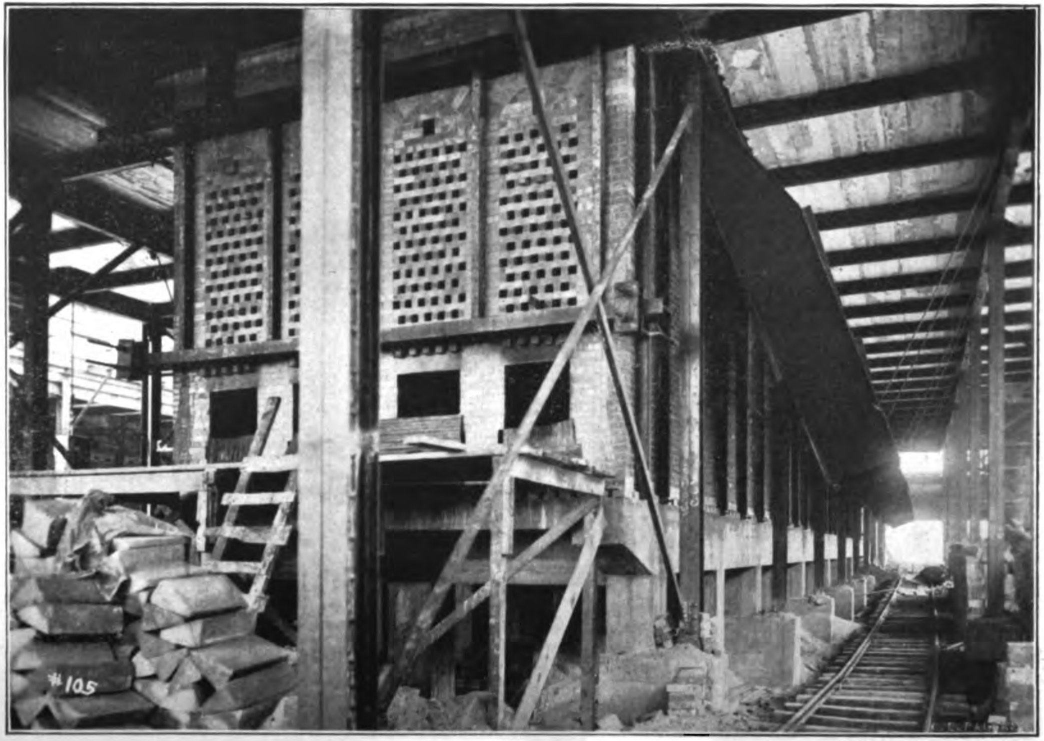

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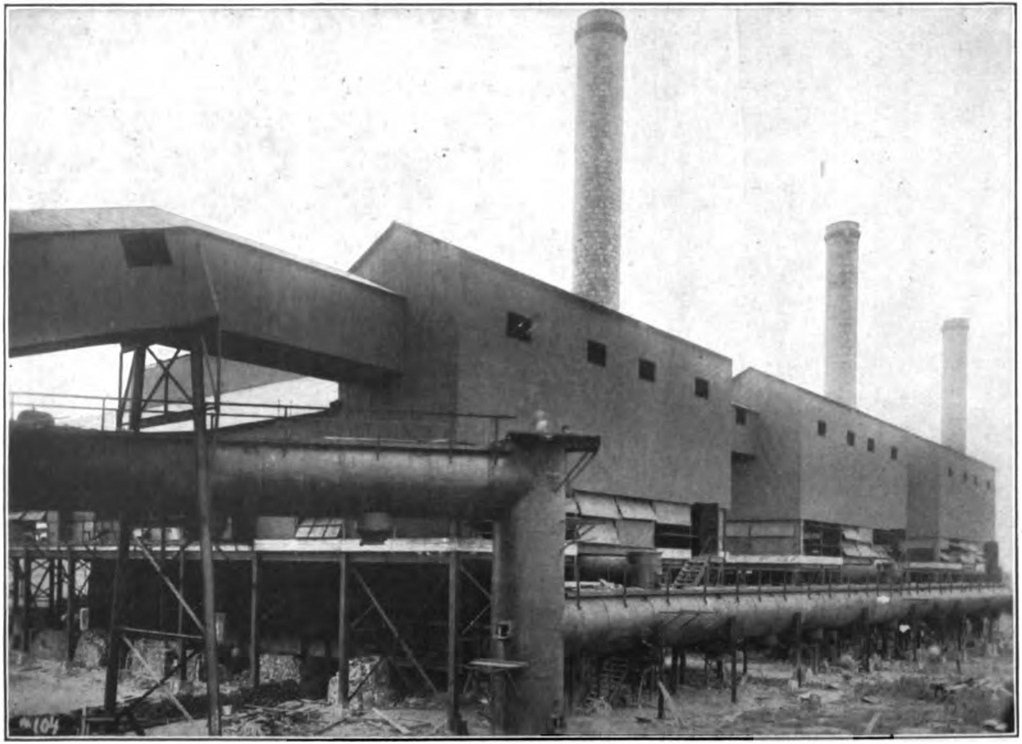

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E. B. Cutten's Patent 1,080,102. Method of smelting zinc oxide free from gangue, effecting reduction in a low blast furnace in a reducing atmosphere under pressure. Gaseous or liquid fuel is used, and the furnace operated intermittently.

891 Die Zinkblende als Steinbildner.—**Kurt Friedrich.** illus. Metallurgie, vol. 5, pp. 114-128. Feb. 22, 1908.

Zinc sulphide as a matte former, gives chemical analyses.

Miscellaneous smelting methods

892 Fink smelting furnace for copper, lead and zinc.—**Edward Fink.** illus. Min. Wld., vol. 37, pp. 797-801. Nov. 2, 1912.

—Abstract: Fink's smelting process. illus. Min. Mag., vol. 7, p. 459. Dec., 1912.

893 Fractional smelting in rotary furnaces. Eng. & Min. Jour., vol. 97, p. 237. Jan. 24, 1914.

Speckceter's German Patent 266,221; smelting miscellaneous ores in a rotary reverberatory furnace.

894 Furnace for purifying zinc from lead and iron. diagr. Met. & Chem. Eng., vol. 17, p. 500. Oct. 15, 1917.

Ziesing's Patent 1,237,141.

895 The Hercules ores.—**P. S. Morse.** Austral. Min. Stand., vol. 49, p. 488. June 12, 1913.

"Report on dezinking processes in operation in Germany." The Pape process at Oker, the Schmidt and DeGraz at Stolberg, and the Savelsburg process.

—Abstract: Schmidt and DeGraz dezinking process. Min. Mag., vol. 9, p. 142. Aug., 1913.

896 The igneous concentration of metallic values from mixed sulphides.—**F. L. Clerc.** illus. Met. & Chem. Eng., vol. 12, pp. 250-53, 307-9, 490. April, May, Aug., 1914.

Includes discussion of the relation of pyritic processes to igneous concentration of zinc.

897 Igneous concentration of zinc ore.—**F. L. Clerc.** Eng. & Min. Jour., vol. 93, pp. 127-31. Jan. 13, 1912.

"Suggestions respecting the use of the Wetherill process, simply reducing and burning the zinc as a method of concentrating zinc ore, the oxide product to go to spelter furnaces."

898 The manufacture of zinc dust. Eng. & Min. Jour., vol. 98, p. 757. Oct. 24, 1914.

Short editorial.

899 New method of extracting zinc. diagr. Min. Wld., vol. 45, p. 502. Sept. 16, 1916.

A cyclic process, using the reverberatory furnace, permitting high percentage of extraction, and leaving the residues in suitable form for further treatment. Invention of H. T. Durant.

900 Plan einer neuen Methode zur Verhuettung von Zinkerzen. —**F. Kellerman.** Berg- u. Huetten. Zeitg., vol. 63, pp. 639-72. July 8, 1904.

—Abstract. Zeits. f. angewandte Chem., vol. 18, p. 178. Feb. 3, 1905.

901 Present status of the Fink furnace.—**H. B. Pulsifer.** illus. Met. & Chem. Eng., vol. 12, pp. 731-33. Nov., 1914.

"Specially designed for the direct smelting of sulphide ores, being a converter-type furnace, using either oil, gas, or soft coal as fuel. It has three or more sets of tuyeres." Performance, recoveries, fume collection, costs.

902 Production of zinc vitriol from the zinc-lead ores of the Harz.—**Bruno Kerl.** Mineral Industry, vol. 4, pp. 83-90. 1895.

903 Recovery of zinc from zincky slags. Met. & Chem. Eng., vol. 14, pp. 103-4. Jan. 15, 1916.

Truax's Patent 1,155,628. The slag is melted in a reverberatory furnace, the hearth of which is composed of reducing material.

904 Reduction furnace. diagr. Electrochem. & Met. Ind., vol. 5, pp. 241-42. June, 1907.

De Laval's rotary furnace and its mode of operation.

905 Reduction of zinc. diagr. Eng. & Min. Jour., vol. 89, p. 974. May 7, 1910.

Loiseau's Patent 947,831; furnace for the reduction of oxidized ores by carbon monoxide.

906 The sulphur smoke question in Germany.—**Alfred Gradenwitz.** Eng. & Min. Jour., vol. 84, p. 311. Aug. 17, 1907.

Government regulations concerning zinc roasting and smelting.

907 Die technische Bedeutung der Staubfrage fuer Zinkhuetten. —**Oscar Gerold.** illus. Metall u. Erz., vol. 12, pp. 403-10, 419-36. Oct. 8, 22, 1915.

Technical importance of the dust problem in zinc smelting. Methods for dust prevention.

908 Verarbeitung von Zinkerzen bei gleichzeitiger Gewinnung von metallischem Blei- und Zink-oxyd. Metallurgie, vol. 9, p. 338. May 22, 1912.

Witter's German Patent 240,365; simultaneous reco ery of lead and zinc from mixed lead-zinc sulphide ores.

909 Verfahren und Ofen zur Scheidung und Gewinnung von Metallen und Metalloxyden aus fluessigen Schlacken und Schmelzen durch Anwendung von Reduktionsmitteln allein oder in Verbindung mit Reaktionsmitteln im Flammofen. diagr. Metall u. Erz, vol. 11, p. 433. June 22, 1914.

Adolphe Desgraz's German Patent, 293,047, for an oven and process for refining and winning metals and metal oxides from fluid slags by means of reduction methods alone, or in connection with reactions in the reverberatory oven.

910 Zinc refining.—**Bruno Kerl.** Mineral Industry, vol. 5, pp. 611-18. 1896.

Effect of the various impurities in crude zinc; refining method of Hohenlohehuette; other methods; electrolytic zinc.

911 Zinc refining. Electrochem. & Met. Ind., vol. 6, p. 381. Sept., 1908.

Ziesing's Patent 893,415.

Production of Zinc Oxide

911a Baghouses for zinc oxide.—**John F. Cregan.** illus., diagr. Eng. & Min. Jour., vol. 106, pp. 126-32. July 20, 1918.

912 The Blum zinc oxide process. diagr. Eng. & Min. Jour., vol. 92, pp. 603-4. Sept. 23, 1911.

U. S. Patent 993,019. Claims that "the Huntington-Herberlein pot is adapted to the manufacture of zinc oxide. Advantages claimed are larger charges, less contamination of the oxide with iron, and production of an easily discharged porous clinker." See also item 918.

—Abstract: Zinc oxide. Min. Mag., vol. 5, p. 312. Oct., 1911.

913 Collecting zinc oxide fume. Met. & Chem. Eng., vol. 12, p. 140. Feb., 1914.

Reynold's Patent 1,082,766; a substitute for canvas bags, in the form of apparatus with mechanical means for scraping the oxide from the collecting medium.

914 Equipment of a zinc oxide plant. Min. Wld., vol. 28, p. 796. May 16, 1908.

Ozark Zinc Oxide Works, Coffeyville, Kansas.

—Same. Electrochem. Met. Ind., vol. 6, p. 305. July, 1908.

915 An experimental plant for saving zinc oxide.—**Paul Speier.** Eng. & Min. Jour., vol. 84, p. 217. Aug. 3, 1907.

Details of an experimental plant at the Rosamunde works in Germany.

916 Die Gewinnung des Zinks aus dem zinkhaltigen Schlacken der unterharzer Huettenbetriebe.—**Hermann Pape.** Glueckauf, vol. 46, pp. 237-39. Feb. 19, 1910.

At the Harz mines at Oker, Germany the slag is ground, briquetted and reduced in a continuous reverberatory furnace, recovering zinc oxide. Wet methods were unsuccessful.

—Same: Treatment of complex zinc sulphide ores at Oker. Eng. & Min. Jour., vol. 89, pp. 819-21. Apr. 16, 1910.

—Abstract. Min. Mag., vol. 2, p. 228. Mar., 1910.

917 Gewinnung von verfluechtigem Zink-oxyd aus zinnhaltigen Rohstoffen durch die vereinigte Einwirkung von Kohlenstoff und Luft. diagr. Metallurgie, vol. 7, p. 128. Feb. 22, 1910.

Recovery of volatilized zinc oxide from tin-bearing materials under the combined action of carbon and air. German Patent 214,735, by H. Muehlinghaus.

918 The Hommel furnace for volatilizing zinc.—**W. Hommel.** diagr. Eng. & Min. Jour., vol. 92, p. 1164. Dec. 6, 1911.

Disputes originally of claims of Blum patent, (item 912). Compares zinc oxide processes; discusses causes of variation in products and the features of the Hommel furnace.

—Abstract: Zinc oxide. Min. Mag., vol. 6, p. 64. Jan., 1912.

919 The lead and zinc pigments.—**Clifford D. Holley,** N. Y., John Wiley & Sons, 1909. 340 pp. illus. 8°.

Manufacture of zinc oxide, pp. 152-74.

920 Manufacture of zinc oxide. diagr. Met. & Chem. Eng., vol. 12, p. 790. Dec., 1914.

J. A. Singmaster's Patents 1,112,853-854; continuous process of producing zinc oxide. Claims improvement on the Wetherill process using stationary grates.

920a The manufacture of zinc oxide at Monteponi.—**F. Sartori.** Eng. & Min. Jour., vol. 106, p. 742. Oct. 26, 1918.

Abstract of a paper in Resoconti delle Riunioni dell' Associazione Mineraria Sarda, Dec., 1917.

921 Oxide of zinc.—**George C. Stone.** diagr. Amer. Inst. Min. Eng., Trans., vol. 57, pp. 682-95. 1917.

"The making of oxide of zinc at Palmerton, Pa., from the products of the New Jersey Zinc Company's Franklin and Sterling Forest mills." Origin and development of the process.

—Same. diagr. Amer. Inst. Min. Eng., Bull. 129, pp. 1217-18. Sept., 1917.

—Same. diagr. Met. & Chem. Eng., vol. 17, pp. 308-13. Sept. 15, 1917.

—Same: Making zinc oxide at Palmerton plants of New Jersey Zinc. Co. Eng. & Min. Jour., vol. 104, pp. 508-12. Sept. 22, 1917.

—Abstract. Min. & Sci. Press, vol. 115, pp. 759-62. Nov. 24, 1917.

922 Production of zinc oxide from low-grade carbonate ore at Leadville. illus. Met. & Chem. Eng., vol. 13, pp. 631-33. Sept. 15, 1915.

Describes plant and operations; Western Zinc Oxide Co., using a Wetherill furnace.

923 Pyrometallurgy of zinc-lead ores. Met. & Chem. Eng., vol. 11, p. 160. Mar., 1913.

Witter's Patent 1,047,360.

924 The treatment of zinc-lead sulphide ores.—**F. L. Bartlett.** Mineral Industry, vol. 5, pp. 619-32. 1896.

Author's smelting method as used at Canon City, Colo.

925 Zinc from low-grade complex ores. Min. & Sci. Press, vol. 115, p. 827. Dec. 8, 1917.

Editorial note on igneous concentration of oxide ores.

926 Zinc burning as a metallurgical process.—**W. R. Ingalls.** illus. Amer. Inst. Min. Eng., Trans., vol. 57, pp. 696-701. 1917.

"Zinc burning is suggested as a designation of the practice of igneous concentration of zinc ores. It seems destined to receive a wider application than the mere making of zinc oxide for pigment."

—Same. illus. Amer. Inst. Min. Eng., Bull. 129, pp. 1229-34. Sept., 1917.

—Same, extended. Eng. & Min. Jour., vol. 104, pp. 457-61. Sept. 15, 1917.

—Abstract. Min. & Sci. Press, vol. 115, p. 432. Sept. 22, 1917.

—Abstract. Met. & Chem. Eng., vol. 17, pp. 519-20. Nov. 1, 1917.

—Abstract. Jour. Soc. Chem. Ind., vol. 36, pp. 1131-32. Nov. 15, 1917.

927 Zinc oxide. Electrochem. & Met. Ind., vol. 6, pp. 79-80. Feb., 1908.

Pape's Patent 877,114.

928 Zinc-oxide and zinc-lead pigment manufacture; how the process requiring pure zinc ores and anthracite fuel was made suitable for complex ores and the use of soft coal. —**William F. Gordon.** illus. diagr. Eng. & Min. Jour., vol. 83, pp. 1033-36. June 1, 1907.

929 Zinc oxide from lead blast furnace slag, as in operation at South Chicago.—**H. B. Pulsifer.** illus. Met. & Chem. Eng., vol. 13, pp. 783-85. Nov. 1, 1915.

"The process consists of smelting the refinery slags in the lead blast furnace with additional lime and considerable coke in the charge; the furnace is run with hot top, and the heavy zinc fume is collected in bags as the finished product of the operation."

—Same. Mex. Min. Jour., vol. 20, pp. 433-34. Dec., 1915.

—Abstract: Recovery of zinc oxide from slag. Min. Mag., vol. 13, pp. 342-43. Dec., 1915.

930 Zinc oxide from lead slag.—**H. B. Pulsifer** and **George Perlstein.** illus. Min. & Sci. Press, vol. 114, pp. 161-63. Feb. 3, 1917.

931 Zinc oxide furnaces.—**John F. Cregan.** diagr. Eng. & Min. Jour., vol. 104, pp. 675-80. Oct. 20, 1917.

"Two general types of zinc oxide furnaces have been developed in the United States as a result of the diverse conditions in ore and fuel supply. Eastern works use a series of separately controlled grates, the zinc fumes passing to a common collecting flue. Western metallurgists prefer a self-contained unit, individual charges controlled by the balance of the whole furnace. The author considers that the Western practice is best adapted to varied ores and fuels." —E. & M. J.

931a Zinc oxide in slags.—**W. Maynard Hutchings.** Eng. & Min. Jour., vol. 79, pp. 959-60. Dec. 24, 1903.

"In slags which are not too basic, zinc oxide is combined as silicate."

—Abstract. Mineral Industry, vol. 12, p. 364. 1903.

932 Zinc oxide process utilizing zinc waste. Min. Wld., vol. 35, p. 1004. Nov. 18, 1911.

Hommel's Patent 1,002,401. "The wastes which accumulate about zinc works contain coke and carbonaceous matter and some zinc. These wastes are used, with the addition of fresh ore, for the production of zinc oxide." See also item 377.

933 Zinc smelting for pigment.—**Evans W. Buskett.** illus. Min. & Sci. Press, vol. 97, pp. 604-5. Oct. 31, 1908.

Method of smelting at Coffeyville.

Smelting Plants

934 Active zinc smelters of the United States.—**C. E. Siebenthal.**

A statistical list arranged by states and companies, showing the retort capacity of each plant, is published in the U. S. Geological Survey's annual compilation, "Mineral Resources of the United States." The same list is usually published in the annual volumes of "The Mineral Industry" and of the "Mines Handbook", and in the early January numbers of the Engineering and Mining Journal, the Mining and Scientific Press, and other mining periodicals. The latest list is included elsewhere in this Bibliography.

935 The American Steel & Wire Company's zinc works. illus. Iron Age, vol. 97, pp. 82-86. Jan. 6, 1916.

Plant at Donora, Pa., operated in 104 days from start of building.

—Abstract: The Donora zinc works. diagr. Min. Mag., vol. 14, p. 114. Feb., 1916.

936 The American zinc smelter at Hillsboro, Illinois.—**Carpel L. Breger.** illus. Min. Wld., vol. 37, pp. 847-50. Nov. 9, 1912.

937 Die Anlage von Zinkhuetten.—**Franz Juretzka.** Zentralblatt der Huetten- und Walzwerke, 1912.

A book on the construction of zinc smelters.

938 The Central Zinc Company's works at Seaton Carew. illus. diagr. Engineering, vol. 80, pp. 141-44. Jan. 29, 1909.

—Abstract: The Central Zinc Co. diagr. Eng. & Min. Jour., vol. 88, pp. 777-78. Oct. 16, 1909.

939 Collinsville smelter of the Bartlesville Company.—**E. H. Leslie.** illus. Min. & Sci. Press, vol. 109, pp. 204-8. Aug. 8, 1914.

—Abstract, in German. Metall u. Erz, vol. 11, pp. 719-20. Dec. 22, 1914.

940 Costs and profits of an up-to-date spelter works.—**J. Gilbert.** Min. Jour., vol. 114, pp. 480-81, 496-98. July 8, 15, 1916.

"A practical consideration of the subject" from an English point of view.

941 Deering plant at American Zinc, Lead & Smelting Company.—**Evans W. Buskett.** illus. Eng. & Min. Jour., vol. 90, pp. 502-3. Sept. 10, 1910.

942 The Donora Zinc Works.—**W. R. Ingalls.** illus. Eng. & Min. Jour., vol. 102, pp. 648-54. Oct. 7, 1916.

Plant of the American Steel & Wire Co.

943 Eine Exkursion auf nordamerikanische-mexikanische Blei-, Zink-, und Kupferhuetten.—**F. Heberlein.** illus. Metall u. Erz, vol. 10, pp. 716-25. Aug. 30, 1913.

—Same: An excursion to North American smelting works; translated by Herbert Haas. Min. & Sci. Press, vol. 107, pp. 713-18. Nov. 8, 1913.

—Abstract: Lead, zinc and copper smelting in America; by O. H. Hahn. illus. Eng. & Min. Jour., vol. 96, pp. 871-75, 909-12. Nov. 8, 15, 1913.

944 Die Huetten der Aktien-Gesellschaft fuer Bergbau, Blei- und Zinkfabrikation zu Stolberg und in Westfalen. Metallurgie, vol. 1, pp. 115-17. Apr. 8, 1904.

945 Improvements at Trail, B. C. Eng. & Min. Jour., vol. 99, p. 290. Feb. 6, 1915.

Lead, zinc and copper smelting.

946 Mill and smelter construction in 1916. illus. Min. Wld., vol. 46, pp. 1-28. Jan. 6, 1917.

Describes several important smelters and electrolytic plants. Similar annual reviews of progress appear in the early January numbers of previous years, of the same journal.

947 The Mineral Point zinc works. illus. Eng. & Min. Jour., vol. 82, pp. 388-91. Sept. 1, 1906.

Makes sulphuric acid and zinc oxide.

948 The Nassau zinc works at Depue, Illinois.—**E. H. Leslie.** illus., map. Min. & Sci. Press, vol. 109, pp. 475-80. Sept. 26, 1914.

—Abstract, in German. Metall u. Erz, vol. 11, pp. 721-22. Dec. 22, 1914.

949 The National Zinc Company, Bartlesville, Okla.—**E. H. Leslie.** illus. diagr. Min. & Sci. Press, vol. 109, pp. 136-41. July 25, 1914.

—Abstract, in German. Metall u. Erz, vol. 11, pp. 718-19. Dec. 22, 1914.

950 The new zinc smeltery at Langeloth.—**W. R. Ingalls.** diagr. Eng. & Min. Jour., vol. 98, pp. 985-89. Dec. 5, 1914.

Plant of the American Zinc & Chemical Co., near Pittsburgh, Pa. Roasting and smelting furnaces are of the Hegeler type.

951 The Palmerton works of the New Jersey Zinc Company.—**O. Pufahl.** Zeits. f. Berg-, Huetten-, u. Salinenwesen im Preuss. Staate, vol. 53, p. 400. 1905. In German.

—Abstract. Zeits. f. angewandte Chem., vol. 20, p. 1744. Oct. 4, 1907.

—Abstract. Eng. & Min. Jour., vol. 81, p. 273. Feb. 10, 1906.

952 Power plant of Granby Mining and Smelting Co. illus. Eng. & Min. Jour., vol. 100, pp. 113-15. July 17, 1915.

953 The Rose Lake smelter of the Granby Company.—**F. H. Leslie**. illus., diagr. Min. & Sci. Press, vol. 109, pp. 395-402. Sept. 12, 1914.

—Abstract: The Rose Lake zinc-smelter. diagr. Min. Mag., vol. 11, p. 263-64. Oct., 1914.

—Abstract, in German. Metall u. Erz, vol. 11, pp. 720-21. Dec. 22, 1914.

954 Ueber die Zinkgewinnung in Dombrowa.—**A. W. Schrubko.** diagr. Metallurgie, vol. 1, pp. 151-56, 178-82. Apr. 22, May 8, 1904.

955 Van Buren smelting plant.—**F. W. Bocking.** illus. Eng. & Min. Jour., vol. 102, pp. 655-58. Oct. 7, 1916.

Plant of Arkansas Zinc & Smelting Corporation.

956 Works of American Zinc & Chemical Co., at Langeloth. Eng. & Min. Jour., vol. 102, p. 816. Nov. 4, 1916.

957 The zinc industry of upper Silesia. Eng. & Min. Jour., vol. 76, p. 120. July 23, 1903.

Statistics for 1901 of several smelters.

958 Zinc-lead smelting plant at Ekibastus, Siberia. Eng. & Min. Jour., vol. 103, p. 266. Feb. 10, 1917.

—Abstract. Jour. Soc. Chem. Ind., vol. 36, p. 342. Mar. 31, 1917.

959 Zinc manufacture in the Pittsburg district. illus. Iron Age, vol. 95, pp. 1064-67. May 13, 1915.

American Zinc & Chemical Co., at Langeloth.

960 Zinc smelting at Bartlesville, Okla.—**E. H. Leslie.** illus., diagr. Min. & Sci. Press, vol. 109, pp. 44-49. July 11, 1914.

—Abstract, in German. Metall u. Erz, vol. 11, pp. 716-18. Dec. 22, 1914.

961 Zinc reduction. Min. Jour., vol. 107, pp. 961, 1004, 1011, 1026; vol. 108, pp. 8-9, 21. Nov. 4, 28, Dec. 5, 12, 1914; Jan. 2, 9, 1915.

Correspondence and discussion on the cost of erecting spelter plants in England.

962 Zinc smelting at Hillsboro, Illinois.—**E. H. Leslie.** illus. Min. & Sci. Press, vol. 109, pp. 280-86. Aug. 22, 1914.

Plant and methods of the American Zinc, Lead and Smelting Company.

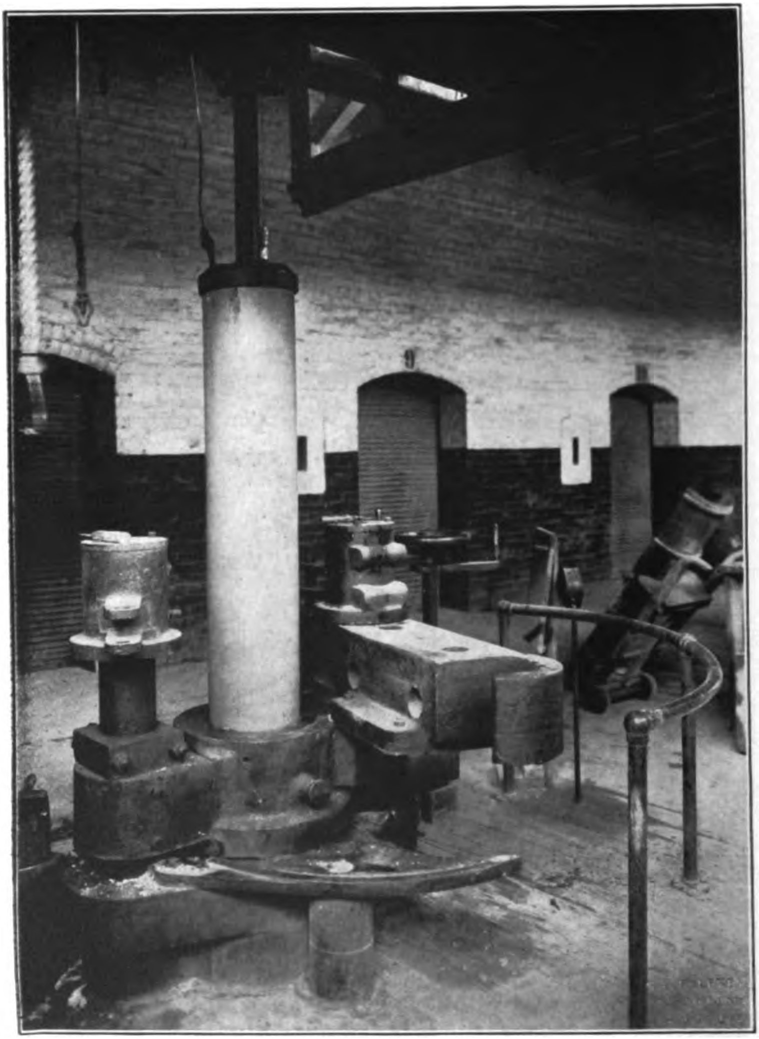
—Abstract, in German. Metall u. Erz, vol. 11, pp. 644-46. Oct. 22, 1914.

963 Zinc smelting in the middle West.—**E. H. Leslie,** San Francisco, Min. & Sci. Press, 1915. 40 pp. illus. paper.

A reprint of the six articles published in the Min. & Sci. Press.

964 The zinc smelting works at Vado Ligure.—**Erminio Ferraris.** diagr. Eng. & Min. Jour., vol. 106, p. 212. Aug. 3, 1918.

Italian smeltery operated by waste gas from coke manufacture.



POTTERY DEPARTMENT, AMERICAN ZINC, LEAD & SMELTING CO.
Retort discharged from Hydraulic Press

PATENTS ON SMELTING

United States

965 448,802. Process of refining zinc.—**Joseph W. Richards,** Philadelphia, Pa. Filed September 27, 1890. Issued March 24, 1891.

The process of refining zinc, which consists in diffusing metallic aluminum throughout a bath of melted zinc, permitting said composite bath to stand in a melted condition for the subsidence of impurities, and finally removing the stratum of refined zinc.

966 453,529. Process of smelting sulphides.—**William L. Austin,** Toston, Mont. Filed Feb. 28, 1889. Issued June 2, 1891.

As an improvement in the art of smelting pyrites, blende, sulphurets, or sulphides, the method of securing continued combustion and smelting without the necessity of the continued use of carbonaceous fuel, which consists in first heating the lower part ot a charge containing one or more of the substances or compounds up to a point where combustion can take place, and then subjecting the charge to the action of a hot-air blast and continuously drawing the molten products as formed away from the path of the blast.

967 453,806. Apparatus for treating ores.—**Eduard Grützner,** Romagna Grube, near Loslau and **Oscar Koehler,** Czernitz, Germany. Filed Mar. 8, 1890. Issued June 9, 1891.

968 469,104. Zinc-furnace.—**Hermann G. Tessmer,** Pittsburg, Kans. Filed Aug. 19, 1890. Issued Feb. 16, 1892.

969 476,789. Furnace for smelting zinc ores.—**Selwyn C. Edgar,** St. Louis, Mo. Filed July 30, 1891. Issued June 14, 1892.

970 478,110. Process of reducing zinc or spelter from ores.—**Christopher James,** Swansea, England. Filed Aug. 18, 1891. Issued July 5, 1892.

A process for the commercial treament of zinc-sulphide ores, consisting in first calcining a part of the ore in a calcining-furnace to the form of an oxide, mixing the calcined ore with rather more than half its weight of crude ore, and smelting the same in the hearth of a neutral or slightly-reducing reverberatory furnace until reduced to zinc and sulphur dioxide, the zinc being volatilized and collected by condensation in a chamber distinct from the furnace

971 482,438. Process of reducing zinc.—**Christopher James,** Swansea, England. Filed Dec. 28, 1891. Issued September 13, 1892.

A process for the treatment of sulphide-zinc ores, consisting of partially calcining the ore, discontinuing the calcination when a portion of the ore is brought to the condition of a sulphate, melting the partially calcined ore in a reverberatory or suitable furnace, and collecting the volatilized zinc by condensation in a chamber distinct from the furnace. Patented also in England, no. 11,563 of 1891; in Belgium, no. 95,763; in Spain, no. 12,373 of 1891; in France, no. 215,113.

972 483,652. Process of reducing zinc.—**Christopher James,** Swansea, England. Filed Dec. 28, 1891. Issued October 4, 1892.

A process for the treatment of zinc ores, consisting in mixing any natural or other oxide of zinc with sulphur or sulphides of any metal, subjecting the same to a melting heat in a neutral or slightly reducing furnace, the relative proportions of the sulphur and oxides being such that the oxygen and sulphur will mutually react to entirely reduce the zinc to a metallic but vaporized condition, and collecting the latter by condensation.

973 483,934. Zinc-furnace.—**Octavius Lumaghi,** St. Louis, Mo. Filed Nov. 10, 1891. Issued Oct. 4, 1892.

974 489,460. Method of producing meltallic zinc.—**Parker C. Choate,** New York, N. Y. Filed Dec. 9, 1891. Issued Janury 10, 1893.

The process of producing metallic zinc which consists in heating an ore of zinc carrying lead in the presence of a reducing agent in a furnace to which air is admitted so as to volatilize the zinc and lead and those constituents of the ore more volatile than zinc, thereby obtaining a zinc lead fume free from the less volatile constituents of the ore; reheating the fume to drive off the constituents more volatile than zinc; subjecting the fume mixed with carbon to heat in a retort; thereby obtaining molten lead and zinc vapors; condensing the zinc vapors in the presence of the molten lead; drawing off the resulting molten alloy, permitting the lead to settle, under the action of gravity and drawing off the superincumbent zinc.

975 489,461. Art of producing metallic zinc.—**Parker C. Choate,** New York, N. Y. Filed July 1, 1892. Issued Jan. 10, 1893.

The process of producing metallic zinc which consists in heating zinc fume mixed with lead fume or pulverized metallic lead, to granulate or condense the fume, heating the product mixed with carbon in a retort to distill the zinc, and finally condensing the zinc vapors and separating the metallic zinc and molten lead.

976 501,189. Process of manufacturing oxide of zinc.—**George T. Lewis,** Philadelphia. Filed Sept. 1, 1891. Issued July 11, 1893.

The method of treating zinc ores containing sulphur, for the manufacture of oxide of zinc which consists in mixing with the ore alkali sufficient to unite with the sulphur and coal sufficient to effect the sublimation of the zinc charging the mixture into zinc oxide furnaces and igniting it to effect the union of the alkali and sulphur and the sublimation of the zinc.

977 540,671. Apparatus for refining zinc spelter.—**Thomas J. Jones,** Pulaski City, Va. Filed Feb. 26, 1895. Issued June 11, 1895.

978 543,256. Process of and apparatus for extraction of zinc.—**Leo V. Lynen,** London, England. Filed Dec. 22, 1893. Issued July 23, 1895.

The process of extracting zinc which consists in enclosing the ore in non-metallic carbonizable envelopes, placing said envelopes in retorts, applying heat and condensing the zinc vapors.

979 554,185. Apparatus for refining zinc.—**George M. Holstein** and **John D. James,** Pulaski City, Va., assignor to the Bertha Mineral Company. Filed July 20, 1895. Issued February 4, 1896.

980 554,184. Process of, and apparatus for defining zinc.—**George M. Holstein** and **John D. James,** Pulaski City, Va., assignors to the Bertha Mineral Company. Filed May 27, 1895. Issued February 4, 1896.

The process of refining zinc and separating it from lead which consists in melting the spelter and causing the lead by its lower melting point, greater specific gravity, and higher volatilizing point to flow to a point of lower level, chilling the metal at this point, to hold the lead below its volatilizating-point and volatilizing and separating the zinc at a temperature below the volatilizing point of lead.

981 555,680. Smelting furnace.—**Christopher Cunningham, jr.,** Brooklyn, N. Y. Filed June 19, 1895. Issued March 3, 1896.

982 572,011. Smelting furnace.—**Herman Huber,** Kansas City, Mo. Filed June 22, 1895. Issued Nov. 24, 1896.

983 578,963. Smelting furnace.—**Charles Bishop,** Tacoma, Wash. Filed October 23, 1896. Issued March 16, 1897.

984 579,750. Manufacture of zinc oxide.—**Wilhelm Hampe** and **Carl Schnabel,** Hanover, Germany. Filed Aug. 1, 1896. Issued March 30, 1897.

The process for preparing zinc oxide consisting in subjecting an intimate mixture of finely divided and dried zinc sulphate and finely divided carbon to an even and correctly gaged temperature.

985 586,910. Smelting furnace.—**John D. McDonald,** Sudbury, Canada. Filed May 18, 1896. Issued June 20, 1897.

986 623,762 Smelting furnace.—**Charles Bishop,** Knoxville, Cal. Filed September 7, 1898. Issued April 25, 1899.

987 633,035. Smelting furnace.—**Joseph V. Otten,** Iola, Kans. Filed Feb. 3, 1899. Issued September 12, 1899.

988 645,178. Process of reducing easily-oxidizable Metals.—**Casper W. Miles,** Cincinnati, Ohio. Filed Dec. 28, 1898. Issued Mar. 13, 1900.

The process of reducing zinc ore which consists in supplying air to a body of fuel, passing the products of combustion around a mass of the ore and carbon, subdividing the current of said products of combustion, passing a portion thereof through said mass of ore and carbon, cooling the vapor so produced and thereby condensing the metallic fumes, mixing the uncondensed residual gas with the remaining portion of the current of the products of combustion and conveying them in contact with the raw ore.

989 645,179. Apparatus for reducing zinc.—**Casper W. Miles,** Cincinnati, Ohio. Filed Sept. 25, 1899. Iss. Mar. 13, 1900. 8 claims.

990 652,076. High-temperature smelting-furnace.—**Wilhelm Borchers,** Aix-la-Chapelle, Germany. Filed April 25, 1899. Issued June 19, 1900.

A high-temperautre smelting furnace having two opposite, vertical fuel-shafts serving alternately as combustion and heat-accumulator chambers, a horizontal passage connecting the lower ends of said fuel-shafts, a vertical smelting-shaft arranged centrally between the fuel-shafts and opening at its lower end into said horizontal connecting-passage, holes in the sides of the fuel-shafts for lighting the fuel therein and discharging the ashes therefrom, plugs for closing said openings, pivotally mounted bails, presser-rods pivoted to said bails for holding said plugs in position, air injector nozzles entering the lower portions of the fuel-shafts opposite said horizontal passage, valved devices for feeding the fuel into, and closing the upper ends of said fuel-shafts, a gas-escape pipe independent of said nozzles arranged in rear of the fuel-shafts and having branch pipes connected respectively with the top portion of said fuel-shafts, and a valve for controlling communication of either branch pipe with the gas-escape pipe, substantially as described.

991 654,066. Retort-furnace.—**Robert E. Lauck,** Kansas City, Mo. Filed Feb. 27, 1899. Issued July 17, 1900.

In a retort-furnace, a retort having its front end projecting through the furnace-wall, and comprising a casing having an inlet port near one end and an outlet-port at the other, and provided with an internal comb, a perforated partition at the front end of the comb and furnace, a non-conductor of heat filling the casing forward of the partition and a shaft journaled in the casing and extending through the partition, and provided with a skeleton spiral conveyer, the teeth of which pass between those of the comb, substantially as described.

991a 656,268. Process of treating ores for recovery of metallic ingredients.—**Benjamin Sadtler,** Denver, Colo., assignor to Albert G. Clark, Cincinnati, Ohio. Filed July 13, 1899. Issued Aug. 21, 1900.

The improvement in the process of treating ores, wherein zinc is combined with iron or other agents which attack fire-clay, consisting in distilling such ores in a retort wherein chemical reactions between the ingredients of the ores and of the retort are excluded, and thereafter treating the residue from such distillation for the extraction of metallic ingredients.

992 665,774. Process for treating sulphide ores.—**Hugh F. Kirkpatrick-Pickard,** London. Filed June 28, 1900. Issued Jan. 8, 1901.

Consists in roasting the ore to the form of oxides, mixing the roasted product with carbonaceous material suitable for coking, forming the mixture into briquettes, and distilling the briquettes under such conditions that they are first coked into coherent masses and finally the zinc is reduced and volatilized while the lead is reduced and the lead and silver retained in minute particles throughout the coke.

993 666,597. Apparatus for treating zinc ores.—**Samuel G. Bridges,** Kansas City, Mo. Filed Nov. 5, 1900. Issued Jan. 22, 1901.

A fume arrester, comprising a pump, a pipe for conveying fumes to the pump, and provided with a water supply and baffle plates, a trap in advance of the pump inlet to prevent the admission of solid matter to the pump, a condensing tank and a vertically disposed pipe leading from the pump into the condensing tank.

994 669,410. Art of extracting zinc from ores.—**Franklin Guiterman,** Denver. Filed Feb. 14, 1900. Issued March 5, 1901.

The process of extracting zinc from its oxidized ores containing corrosive metallic oxides, which consists in introducing the oxidized ore in a divided or granular condition into a receptacle, heating the ore through the walls of said receptacle, to a high temperature, but below the volatilizing temperature of zinc, maintaining the ore in a permeable and mobile condition during the operation of heating, introducing into intimate contact with said ore a current of reducing-gas, under pressure, throughout the heating, continuing the heating and the action of the reducing-gas until the corrosive metallic oxides are reduced as described, withdrawing the ore and finally recovering the metallic zinc therefrom by distillation.

995 669,411. Retort for treating ores.—**Franklin Guiterman,** Denver, Colo. Filed Feb. 21, 1900. Issued March 5, 1901. 7 claims.

996 669,750. Method of making zinc-white.—**David B. Jones,** Chicago, Illinois. Filed July 14, 1900. Issued March 12, 1901.

Consists in imparting a cyclonic swirl to a mixed charge of powdered ore, fuel and flux by projection it tangentially in divided masses through aid of an air blast into the furnace, setting the charge aflame, expanding the resultant pigment fumes and combustion products freely upward toward the exit and simultaneously separating and trapping the associated non-volatile constituents or slags by arrest thereof during the centrifugal swirl.

997 674,936. Furnace for the reduction of zinc ores.—**Harrison B. Meech,** Denver, Colo. Filed Sept. 26, 1900. Issued May 28, 1901.

998 681,609. Process of treating zinc-bearing complex ores.—**Guy de Bechi,** Paris, France. Filed Mar. 19,1900. Issued August 27, 1901.

A process for the treatment of zinc-bearing complex ore containing zinc, copper, lead, and silver, which consists in pulverizing said ore, mixing the pulverized ore with binding material and a chloride salt of an alkali or an alkaline-earth metal, compressing said mixture into blocks, roasting said blocks, and finally introducing a reducing agent and smelting the blocks, the entire process being carried out in one operation at such a temperature that fumes of chlorides and oxides of zinc and copper are evolved and that metallic lead and silver are recovered, and condensing the said fumes.

999 686,915. Treatment of zinc ores.—**Henri M. Taquet,** Argenteuil, France. Filed Mar. 29, 1901. Issued November 19, 1901.

The herein-described process which consists in first subjecting a solution containing sulphate and chloride of zinc to the action of oxide of an alkaline-earth metal and thereby obtaining by precipitation an artificial product composed of oxide of zinc and sulphate of the alkaline-earth metal and then subjecting this product mixed with carbon to heat and thereby obtaining at one and the same operation metallic zinc and a residue of alkaline-earth-metal sulphide.

1000 692,148. Process of recovering zinc from sulphide ores.—**Hugh F. Kirkpatrick-Picard,** London, England. Filed July 9, 1901. Issued January 28, 1902.

The process of treating sulphide ores containing zinc and other metals, which consists in mixing the unroasted ores with a basic material capable of combining with sulphur, and carbonaceous material suitable for coking, forming the material into briquets and distilling the briquets under such conditions that they are first coked into coherent masses and finally the zinc is reduced and volatilized while the resulting sulphide and the non-volatile metals are retained in minute particles throughout the coke. Patented also in England, No. 2151 of 1900.

1001 694,137. Zinc-furnace.—**George G. Convers** and **Arthur B. DeSaulles,** South Bethlehem, Pa. Filed September 14, 1898. Issued February 25, 1902.

1001 694,947. Process of smelting zinc.—**Samuel Davis,** Iola, Kansas. Filed June 5, 1900. Issued March 11, 1902.

The process of smelting zinc, consisting in placing a mixture of zinc oxide and particles of non-metallic refractory substances within a retort, exteriorly heating the latter, passing a current of hydrocarbon gas through the charge, whereby reduction is effected, conducting the gas and the vaporized metal carried thereby through a condenser to deposit the metallic zinc and finally permitting the gas to escape.

1003 695,376. Production of zinc-dust.—**George G. Convers** and **Arthur B. DeSaulles,** South Bethlehem, Pa. Filed September 14, 1898. Issued March 11, 1902.

The process of obtaining the substantially maximum yield of zinc-dust or blue powder from a given retort charge, which consists in preliminarily heating the charge to effect the distillation of zinc, receiving the metallic zinc vapors given off from the charge, in their substantial entirety from the muffle into a collecting chamber, thereby maintaining their temperature throughout above the point of liquifaction of any substantial portion of the vapor until they have entered the collecting chamber, and immediately condensing them in said chamber under such conditions of temperature and expansion as will precipitate them in substantially their entirety in the form of zinc dust.

1004 698,163. Process of refining spelter.—**Charles Wessell,** New York, N. Y. Filed April 29, 1901. Issued April 22, 1902.

The process of refining spelter which consists in treating the refined spelter with phosphorous, or with phosphorous and magnesium. Patented also in England, No. 22,387 of 1901.

1005 699,969. Process of making spelter.—**Oskar Nagel.** New York, N. Y. Filed Nov. 13, 1901. Issued May 13, 1902.

An improved process for condensing zinc vapors to spelter which consists in cooling the vapors in an atmosphere of water-gas. Patented also in England, No. 10,953 of 1902.

1006 700,311. Treatment of complex and refractory ores.—**Francis Ellershausen,** London, England, assignor to the Sulphides Reduction (New Process), Ltd., London. Filed Feb. 15, 1900. Issued May 20, 1902.

The process of treating complex and refractory ores containing lead, silver and zinc which consists in smelting the raw ores, positively drawing off the fumes and gases, and churning them with water to condense and mix them therewith, settling out the lead, silver and part of the zinc compounds from the resulting liquor, as a sludge, separating and drying the sludge, mixing black ash with burnt lime and passing water therethrough and evaporating the resulting liquid to obtain a molten crude caustic alkali, fusing the dried sludge, with said molten crude caustic alkali, thereby precipitating the lead in metallic form, separating the lead and treating the residual molten mass with water to dissolve out the caustic soda and precipitate sulphide of zinc, treating the liquid from which the sludge was separated and which contains the zinc sulphate with the caustic soda, thereby precipitating the zinc and converting the caustic soda into sulphate of sodium and recovering the sulphate of sodium. Patented also in England, No. 483 of 1900.

1007 701,457. Apparatus for obtaining zinc or other volatile metals from ores or mattes.—**John Armstrong,** London, England. Filed Aug. 30, 1900. Issued June 3, 1902. 6 claims.

1008 702,526. Spelter furnace.—**Alfred Ash,** Peterswood, England. Issued June 17, 1902.

A reverberatory furnace for refined hard spelter, having an inclined liquation bed, with refining and collecting pits adjacent to the lower edge.

1009 701,458. Process of obtaining zinc or other volatile metals from ores or mattes.—**John Armstrong,** London, England. Filed August 30, 1900. Issued June 3, 1902.

The process of smelting compounds of volatile metals, which consists in heating them with carbon out of contact of air, reducing and vaporizing them in a reducing atmosphere consisting largely of carbon monoxide, and condensing them by passing the metallic vapors and the carbon monoxide into a bath of the same metal that is being condensed, which bath is maintained in a molten state, but not much above the melting-point, condensing the metal in said bath and passing the carbonic oxide through the same. 5 claims. See also U. S. Pat. 713,043, Nov. 4, 1902.

1010 701,885. Retort.—**Evan H. Hopkins,** South Kensington, England. Filed Oct. 18, 1901. Issued June 10, 1902. Patented in England, no. 22,554 of 1900.

1011 702,764. Process of extracting zinc.—**Jules L. Babe** and **Alexis Tricart,** Paris, France. Filed June 29, 1900. Issued June 17, 1902.

The process of extracting metallic zinc from ores poor in zinc, which consists in forming briquets from a mixture of the ore, carbonate of soda and carbon, subjecting said briquets to the action of heat suitable for driving off the zinc-vapors from said briquets, condensing the said vapors driven off, whereby a condensation product containing zinc oxide is formed, mixing said product with carbonate of soda and carbon, subjecting said mixture to a suitable temperature for driving off the metallic zinc in the form of vapors, and condensing said vapors.

1012 701,601. Smelting-furnace.—**Charles Laughlin,** St. Louis, Mo. Filed April 11, 1901. Issued August 26, 1902.

1013 707,602. Smelting furnace.—**Charles Laughlin,** St. Louis, Mo. Filed Dec. 28, 1901. Issued August 26, 1902.

1014 708,044. Process of obtaining zinc.—**Evan H. Hopkins,** South Kensington, England. Filed July 1, 1901. Issued September 2, 1902.

The process of obtaining zinc free from lead, from the mixtures of the oxides of zinc and lead which consists in heating carbon to incandescence, heating the oxides mixed with carbonaceous materials in a closed retort and passing the products of distillation upward through the incandescent carbon. Patented also in England, No. 708,044, of 1900; France, 325,903, Oct. 25, 1902.

1015 708,438. Zinc-furnace.—**William C. Wetherill,** Joplin, Mo. Filed Oct. 12, 1900. Issued September 2, 1902. 12 claims.

1016 710,217. Furnace for separating zinc from ores.—**Amedee M. G. Sebillot,** Paris, France. Issued Sept. 30, 1902.

In a furnace for extracting zinc from ores, a combustion-chamber divided into front and rear compartments adapted to hold the ores to be treated, and charcoal, respectively, air-blast pipes communicating with the front compartment, said compartments connected by openings in their division-wall, and condensing-chambers connected by suitable openings with the upper and lower portions of said compartment of the furnace.

1017 713,043. Process of smelting and refining volatile metals. —**John Armstrong,** London, England. Filed March 24, 1902. Issued November 4, 1902.

The process which consists in smelting ores containing zinc and like volatile metals and other less volatile metals with fluxes, so as to slag the more volatile metals, condensing any fumes in the form of poussiere, returning the same to the furnace, drawing off the slag and distilling it with fuel to obtain the zinc and other very volatile metals and tapping out the mixture of lead, silver and other like metals.

1018 714,502. Process of extracting zinc from zinc-skimmings.— **Herman C. Meister,** St. Louis, Mo. Filed Aug. 16, 1902. Issued Nov. 25, 1902.

A process of converting zinc compounds of zinc skimmings into oxide of zinc, which consists in treating the zinc skimmings with the oxide of an alkali or the oxide of an alkaline earth in the presence of moisture.

1019 714,503. Process of extracting zinc from zinc-skimmings.— **Hermann C. Meister,** St. Louis, Mo. Filed Aug. 16, 1902. Issued Nov. 25, 1902.

A process of converting zinc compounds of zinc skimmings into carbonate of zinc which consists in treating the zinc-skimmings with the carbonate of an alkali in the presence of moisture.

1020 714,615. Furnace.—**Erminio Ferraris,** Monteponi, Sardinia, Italy, assignor of one-fourth to W. R. Ingalls, Lynn, Mass. Filed Aug. 16, 1901. Issued Dec. 2, 1902.

1021 715,024. Extracting metals from complex or sulphide ores. —**John C. Clancy** and **Luke W. Marsland,** Sydney, New South Wales. Filed Mar. 2, 1901. Issued Dec. 2, 1902.

A process of extracting and recovering gold, silver, lead, zinc, and other metals from mixed or complex sulphide ores consisting essentially in the following successive operations; heating the ore with the addition or admixture of lead sulphate in a cupola or blast-furnace so as to convert the required amount of lead and the whole of the zinc and other volatile metals contained in said mixture more or less wholly into fume, spraying dilute sulphuric acid upon the fume and gaseous products of decomposition to convert the fumed metallic oxides into their corresponding sulphates, recovering the lead sulphate used for mixing with the ore and the zinc and other volatile metals from the sulphates deposited in the first-named or fume chamber, recovering the metallic contents from the residue remaining in the furnace by smelting. Patented also in England, No. 9,503 of 1901.

1022 715,238. Process of refining lead and zinc fumes.—**Frank L. Bartlett,** Canon City, Colo. Filed Mar. 25, 1901. Issued Dec. 9, 1902.

Consists in subjecting a collected mass or body of the fume to the action of heated carbonic-dioxide gas.

1023 717,299. Extraction of zinc and lead from sulphide ores.—**George C. Stone,** Newark, N. J. Filed May 24, 1899. Issued December 30, 1902.

The method of separating zinc and lead from sulphide ores, which consists in smelting the sulphides, oxidizing the volatile constituents at their exit from the smelting furnace, cooling the resulting fumes and products of combustion to a temperature not exceeding 180° Fahrenheit and passing them into contact with a solvent which will dissolve out one of the metals and not the other, collecting the resulting solution and enriching and concentrating it by passing it into further contact with the fume-current. 3 claims.

1024 718,222. Process of reducing zinc from its oxides.—**Wilhelm Schulte.** Overpelt-lez-Neerpelt, near Limburg, Belgium. Filed April 22, 1902. Issued January 13, 1903.

A process for smelting oxidized zinc ores which consists in impregnating the ore with hydrocarbons, mixing it with a quantity of coal less than necessary for effecting alone a reduction of the ore, and then distilling the mixture. Patented also in France, No. 318,265.

1025 720,664. Zinc-smelting furnace.—**Joseph P. Cappeau,** Joplin, Mo. Filed Oct. 22, 1902. Issued February 17, 1903.

The combination with a zinc-smelting furnace, of a series of air-pipes arranged at intervals at the front of the furnace, a main air passage adjacent to the lower ends of the air-pipes, communicating with them and open at its end to the outer air, and discharge ports in the air-pipes communicating with the interior of the furnace, adjacent to the retorts, whereby air is conveyed to the furnace by a natural draft and distributed at numerous intervals to the furnace adjacent to the retorts. 5 claims.

1026 727,297. Apparatus for producing zinc-dust.—**George G. Convers** and **Arthur B. De Saulles,** South Bethlehem, Pa. Filed September 14, 1898. Issued May 5, 1903.

An apparatus for the recovery of zinc dust or blue powder, comprising a plurality of muffles arranged at different heights, a furnace for heating the same externally, and an expansion-chamber, common to the series, the rear wall of the expansion chamber being formed by the front wall of the combustion chamber, thereby providing direct and jointless communication between the muffles and expansion-chamber, said expansion-chamber being of such capacity relatively to the retorts as to immediately expand and solidify the zinc-vapors into zinc-dust.

1027 727298. Apparatus for producing zinc-dust.—**George G. Convers** and **Arthur B. De Saulles,** South Bethlehem, Pa. Filed September 14, 1898. Issued May 5, 1903.

Apparatus for the recovery of zinc-dust or blue powder, comprising a zinc-distilling muffle, a furnace for heating the same externally, and a collecting and expansion chamber immediately adjacent to the muffle and of such relative size and capacity as to be kept heated by the zinc vapors and to precipitate the said vapors therein in their substantial entirety as zinc-dust.

1028 731,184. Process of obtaining zinc.—**Evan H. Hopkins,** London, England. Filed June 16, 1902. Issued June 16, 1903.

The process of reducing and collecting zinc which consists in subjecting a material which contains zinc to heat in the presence of a reducing agent, excluding air and the heating flame therefrom, and in conveying the zinc-vapors into and condensing all of them in a mass of carbon from which air is excluded and which is heated to a temperature between those at which zinc solidifies and volatilizes. 5 claims. Patented also in England, No. 12,859, of 1902.

1029 735,894. Treatment of zinc or other ores.—**William B. Middleton,** London, England. Filed Dec. 27, 1901. Issued August 11, 1903.

In the treatment of zinc-ores to produce zinc-white, the process which consists in heating the ore, transferring the said ore in a layer onto the top of the fuel previously ignited till it burns clear, reducing it directly in contact with such fuel, adding a fresh layer of fuel when the ore is spent, heating a fresh quantity of ore and transferring it to the fresh fuel and so on. Patented also in England, No. 12,274, of 1901.

1030 735,902. Method of treating zinc ores.—**Carl V. Petraeus,** Iola, Kansas. Filed Nov. 19, 1901. Issued Aug. 11, 1903.

The method of treating zinc ores for the economic utilization of their metallic contents, which consists in mixing said ores with carbon, subjecting the mixture to high heat with exclusion of air to smelt and volatilize the greater portion of the zinc, recovering the volatilized zinc by condensation, subjecting the unvolatilized residue, consisting of coke and ore, to heat in an oxidizing atmosphere to oxidize the zinc, and any lead therein, and drive them off as a fume, recovering said fume by screening the furnace gases, and finally subjecting the recovered fume to a temperature indicated by a red heat, to whiten it.

1031 735,903. Method of manufacturing spelter from zinc ores. —**Oliver H. Picher,** Joplin, Missouri. Filed Aug. 26, 1899. Issued Aug. 11, 1903.

The method of manufacturing spelter from zinc ore containing lead and iron pyrites which consists first in eliminating the lead contents of the ore by heating it in contact with air to a temperature sufficient to sublime the lead, but below that at which zinc is sublimed in material quantity, then desulphurizing the residue and rendering the pyrites porous by calcination, then separating the altered pyrites from the desulphurized residue and finally treating the residue in admixture with carbon retorts to volatilize the zinc.

1032 736,008. Treatment of zinc ores.—**Carl V. Petraeus,** Iola, Kansas. Filed Nov. 19, 1901. Issued August 11, 1903.

The method of treating zinc ores which consists in mixing such ores with carbon, subjecting the mixture to high heat with exclusion of air, in order to reduce and distil a large portion of the zinc, condensing the distilled metal, recovering the zinc fumes which escape from the distilling and condensing apparatus, mixing said fumes with the carbonaceous and metal-bearing residue of the distilling process, treating said mixture to reduce and oxidize the metals in order to drive off its metallic contents as a fume, and recovering said fume by screening the furnace gases.

1033 736,009. Treatment of ores containing zinc or other metals. —**Carl V. Petraeus,** Iola, Kansas. Filed Nov. 19, 1901. Issued August 11, 1903.

The method of treating zinc ores containing other valuable metals, which consists in mixing said ores with carbonaceous material, smelting and volatilizing a large portion of the zinc by heating the mixture with exclusion of air, recovering the volatilized zinc by condensation, treating the metal-bearing residue of the distillation process in admixture with carbon to drive off the zinc as an oxide fume and, at the same time, cinder together the residue containing the other valuable metals, by heating the mixture to a sufficient temperature in an oxidizing atmosphere, and then smelting said cindered residue, to recover its contained metals.

1034 736,010. Method of smelting zinc oxide.—**Carl V. Petraeus,** Iola, Kansas. Filed Nov. 19, 1901. Issued August 11, 1903.

The method of making zinc from sublimated zinc oxide which consists in first heating the oxide to a red heat to eliminate sulphur and condense the zinc oxide then intimately mixing the densified oxide with carbon and wetting the mass prior to charging it into the retorts, and finally smelting the mixture in retort furnaces.

1035 742,830. Metallurgical process.—**Oliver W. Brown,** Bloomington, and **William F. Oesterle,** Marion, Ind. Filed May 14, 1903. Issued November 3, 1903.

The process of simultaneously producing metallic zinc and a carbide, which consists in mixing with the zinc ore, carbon and an oxide of a metal having a greater affinity for carbon than for the zinc and then heating the mixture to a temperature sufficient to produce the products.

1036 751,401. Method of treating refractory ores.—**Edward H. Miller,** London, England. Filed November 27, 1903. Issued Feb. 2, 1904.

The process for the treatment of refractory lead-zinc ores consisting in mixing the ore with silicious matter and pitch, with the addition of lime according to the silver value of the ore, forming the mixture into dry blocks, packing the dry blocks into a furnace with suitable air spaces, and sprinkling the layers with lime and gradually raising the temperature, whereby substantially the whole zinc content of the ore is converted into metallic zinc which distils over, and the lead and silver contents of the ore are also converted into the metallic state in which state they are retained in the residue in the retort and recovered therefrom by melting out. Patented also in England, No. 20,465, of 1902.

1037 754,141. Process of obtaining zinc.—**Evan H. Hopkins,** South Kensington, London, England. Filed June 4, 1903. Issued March 8, 1904. Patented also in England, No. 12,859 of 1902.

Improvement on U. S. Patent 731,184.

1038 757,059. Furnace for producing zinc.—**Paul Schmieder,** Lipine, Germany. Filed October 29, 1902. Issued April 12, 1904.

In a furnace for extracting zinc, the combination of a vertical receptacle or shaft for the charge of ore mixed with fuel, with a device for heating the upper part of the charge through the walls of said receptacle, a number of condensers or collectors of the liquid zinc for this reduction-chamber, a number of tuyers in the lower part of the shaft which is not arranged to be heated, an oxidation-chamber, a condensing chamber and openings above the tuyers and suitable channels for leading the gases from this oxidation-chamber for the slag to the condensing-chamber.

1039 766,279. Process of making spelter.—**Oskar Nagel,** Hamborn, Germany. Filed Jan. 12, 1903. Issued August 2, 1904.

An improved process for making spelter from zinc oxidic ores, which consists in subjecting the material to the reducing effect of gaseous or gasified hydrocarbons heated previously to entrance in the reducing chamber, and in cooling the resulting zinc vapors in an atmosphere of such gas.

1040 775,359. Apparatus for the extraction of zinc.—**Charles S. Brand**, Knowle, England. Filed Feb. 6, 1904. Issued Nov. 22, 1904.

The combination with means for the extraction of zinc, of the condensing-chamber, the passage connecting the means for extraction of zinc with the condensing-chamber and a mass of chemically-inert and refractory or non-combustible material in said passage. Patented also in England, No. 263 of 1904; in France, No. 341,345.

1041 775,360. Apparatus for the extraction of zinc.—**Charles S. Brand,** Knowle, Eng. Filed Feb. 6, 1904. Issued Nov. 22, 1904.

In the extraction of zinc, the combination consisting of a retort, or detachable nozzle or condensing-pipe having a free space in its interior, or an internal bridge or baffle-piece projecting from the under side of the said pipe toward the upper side of the same and dividing the pipe interior into fore and aft areas or chambers communicating only at their upper sides, a rearwardly inclined lower surface in the aft area or chamber, a perforated closure at the rear end of the pipe and a detachable partial closure at the forward end of the same. Patented also in England, No. 3,628 of 1904; in France, No. 341,346.

1042 792,773. Regenerative retort-furnace.—**Herman Hegeler** and **Julius W. Hegeler,** Lasalle, Ill. Filed Dec. 12, 1903. Issued June 20, 1905.

In a regenerative retort-furnace of the class described, the combination with the two-compartment retort-chamber, the compartments communicating at the top, of regenerators located beneath each of said compartments, a series of flues connecting a regenerator with each compartment of the retort-chamber and communicating with the space therein below the lowermost tier of retorts only, and another series of flues connecting a regenerator with each compartment of the retort-chamber and having several ports at different heights and communicating with the spaces beneath the lower and other tiers of retorts. 8 claims.

1043 794,799. Zinc-smelting furnace.—**Edward C. Hegeler,** Lasalle, Ill. Filed Feb. 2, 1903. Issued July 18, 1905.

In a zinc-smelting furnace of the class specified, a long, horizontal retort chamber through which the gases pass unobstructed, except by the retorts, in the direction of its greatest extension, having staggered recesses in its roof and its bottom and in combination with the retorts arranged in the space outside the recesses and separated into groups by open vertical spaces, the recesses in the roof and bottom being arranged alternately over and under the space occupied by a group of retorts and the pair of open vertical spaces adjacent thereto.

—Described. Jour. Soc. Chem. Ind. vol. 24, pp. 1175-76. Nov. 30, 1905.

1044 806,121. Zinc furnace.—**Emile Dor-Delattre,** Budel, Netherlands. Filed Apr. 12, 1905. Issued Dec. 5, 1905.

A gas heated zinc furnace having independent air and gas channels, and a chamber adapted to support a series of retorts, the roof of the chamber having formed therein a plurality of narrow apertures each communicating with both said air and gas channels, said apertures being each arranged in line with a retort in said chamber, and a plurality of retorts being arranged in each of the spaces between said apertures. 5 claims. Patented also in France, No. 358,150; in England, No. 19,655 of 1905.

1045 807,271. Process of extracting metals from their sulphides. —**Antoine M. Imbert,** Grand-Montrouge, France. Filed Dec. 22, 1903. Issued December 12, 1905.

The process of extracting zinc and lead from a complex ore containing blende and galena, consisting in adding to the ore the necessary copper and fluxes; in heating the mixture to the vaporization temperature of zinc, but maintaining the lead at a temperature below the vaporizing point of this latter metal in condensing the vaporized zinc and drawing off the molten lead; in separating the resulting scoriae and copper sulphide; and in recovering the copper from the sulphide in order that it may be used over again.

1046 812,619. Method of preserving the inner walls of furnaces. —**Friederich C. W. Timm,** Hamburg, Germany. Filed Apr. 21, 1905. Issued Feb. 13, 1906.

1047 813,021. Method of charging retorts, muffles, furnaces and the like.—**Augustin L. J. Queneau,** South Bethlehem, Pa. Filed Jan. 16, 1905. Issued February 20, 1906.

1048 813,022. Charging-machine.—**Augustin L. J. Queneau,** South Bethlehem, Pa. Filed Jan. 16, 1905. Issued Feb. 20, 1906.

1048a 813,023. Apparatus for charging retort-benches.—**Augustin L. J. Queneau.** Filed Jan. 16, 1905. Issued Feb. 20, 1906.

1049 826,557. Process of reducing metals.—**George L. Fogler,** Pittsburg, Pa. Filed Aug. 19, 1904. Issued July 24, 1906.

The continuous process of smelting ores which consists in forcing previously heated reducing gases into a reducing-zone maintained in the ore, furnishing a supply of air insufficient to effect complete combustion around the gas-supply whereby the incompletely burning gases reduce the ores, maintaining a partial vacuum above the charge whereby the gaseous products of the incomplete combustion and of the reduction expand into the upper portion of the charge and rapidly leave the reduction zone; continuously maintaining the reducing atmosphere in the furnace, drawing off the products of the smelting process and supplying fresh ore and flux from time to time.

1050 826,568. Flux for extracting metals from ores.—**Adolf Gutensohn,** Southend, England. Filed Nov. 3, 1905. Issued July 24, 1906.

A flux for the purposes stated, consisting of the admtxture of borate of manganese with carbon and slag-liquefyin materlal, consisting of fluorspar.

1051 827,418. Process of refining zinc and other metals.—**Jacob Callmann** and **Rudolf Bormann,** Berlin, Germany. Filed Feb. 15, 1906. Issued July 31, 1906.

The continuous process of refining zinc and other metals, which consists in melting the metal passing it in a molten condition and in a thin stream or layer through a suitable conduit, and subjecting it to a gradually-increasing heat in said conduit, until the boiling temperature thereof is reached. Patented also in England, No. 3,252 of 1906; in France, No. 362,802. See also item 752.

1052 830,283. Apparatus for obtaining zinc.—**John Armstrong,** London, England. Filed Sept. 20, 1905. Issued Sep. 4, 1906.

In an apparatus for obtaining zinc a high narrow reducing-chamber with means for feeding the same at top and at the same time sealing it from the air, means for discharging it at the bottom with air seal, the said chamber being made slightly tapered so as to be wider at the bottom than at the top and extending in depth and height beyond the heating-flues whereby the material easily descends and is cooler at the top and bottom than at the intermediate zone of reduction. 10 claims. Patented also in England, No. 20,543 of 1905.

1052a 831,165. Roasting furnace.—**Frank Klepetko,** New York, Filed Nov. 6, 1905. Issued Sept. 18, 1905.

1053 833,472. Process of obtaining metals and compounds thereof.—**Herman Mehner,** Berlin, Germany. Filed February 18, 1904. Issued October 16, 1906.

The process which consists in bringing zinc ore in contact with carbon and an incandescent fluid heat carrier, leading off the zinc vapors and gases generated for condensation and separation. 11 claims.

1054 837,446. Means for carrying off gases from retorts while being charged.—**Martin Ziegler,** Beuerberg, Isartalbahn, Germany, assignor to Oberbayrische Kokswerke und Fabrikchemischer Produkte Aktien-Gesselschaft, Munich, Germany. Filed Aug. 1, 1906. Issued December 4, 1906.

1055 839,160. Zinc-smelting furnace.—**William Lanyon,** Iola, Kans. Filed July 31, 1906. Issued Dec. 25, 1906.

A zinc furnace constructed with a center wall in which is formed a flue, means whereby air and gas are delivered into the ends of said furnace, and means whereby the air and gas during combustion are caused to pass upward between the retorts in the ends of the furnace, downward between the retorts in the center of the furnace, and thence outward through the flue in the center wall. 12 claims.

1056 834,872. Furnace for obtaining zinc from zinc ores.—**Adolphe Desgraz** and **Paul Schmidt,** Hanover, Germany. Filed Sept. 13, 1906. Issuer Feb. 12, 1907. Patented also in France, no. 367,368.

1057 851,187. Process of treating zinc and lead ores.—**John Thelberg,** New York, N. Y. Filed July 16, 1902. Issued April 23, 1907.

The process of treating virgin ores containing zinc sulphide or lead sulphide or both for the purpose of producing oxide of zinc, sulphates of zinc and lead and sulphuric acid, which consists in forcing a superheated mixture of steam and air into a body of such ore in a furnace, which ignites and oxidizes the sulphur, zinc and lead, then conveying the volatilized sulphates and oxides, together with the gases out of the furnace, cooling the gases, the volatilized oxide and sulphates to a suitable temperature, separating the condensed zinc oxide and zinc and lead sulphates from the gases, and finally conveying the separated gases, consisting of sulphur dioxide and nitrogen, into any suitable apparatus for the conversion of the sulphur dioxide into sulphuric acid. Patented also in England, No. 3,789 of 1907.

1058 851,998. Process of filling zinc-retorts.—**John D. James,** Pulaski, Va. Original application filed Jan. 3, 1906. Divided and this application filed Nov. 12, 1906. Issued Apr. 30, 1907.

1059 852,440. Process of reducing zinc ores.—**G. P. de Laval,** Stockholm, Sweden, assignor to Société Anonyme Métallurgique Procédes de Laval, Frankfort on-the-Main, Germany, a Corporation of Belgium. Filed July 15, 1905. Issued May 7, 1907.

The process of reducing zinc ores which consists in subjecting a pulverous charge containing the zinc ore mixed with material necessary for carrying out the chemical reactions in a suitable furnace to a rapid rotating or whirling motion produced by means of a current of gas. Patented also in France, No. 356,097.

1060 870,668. Process of desulphurizing and reducing sulphide ores.—**Eduard Dedolph,** Marysville, British Columbia, Canada. Filed Mar. 23, 1907. Issued Nov. 12, 1907.

The process of desulphurizing and reducing sulphide ores, which consists in roasting the ground ore intimately mixed with finely divided carbonaceous fuel, in such fashion as to oxidize the sulphur and a portion only of the fuel, and then smelting the product consisting of the roasted ore and the unconsumed fuel.

1061 875,578. Process of treating zinc and lead sulphide ores.—**Antoine H. Imbert,** Grand-Montrouge, France. Filed Nov. 9, 1906. Issued Dec. 31, 1907.

Consists in heating the sulphide in the presence of an oxide of such a character as to form a dissolvent for the said metallic sulphides with a metal having a greater affinity for sulphur than the metal of the sulphide. 11 claims. Patented also in England, No. 10,303 of 1906.

1062 875,579. Metallurgical treatment of sulphurous ores by the precipitation process.—**Antoine H. Imbert.** Grand-Montrouge, France. assignor to Imbert Process Co., New York, N. Y.. Filed June 6, 1907. Issued Dec. 31, 1907.

Consists in heating the sulphide in the presence of an oxide and a sulphide of such a character that they will form a dissolvent for the said metallic sulphides with a metal having a greater affinity for sulphur than the metal of the sulphide being reduced. 15 claims. Patented also in England, No. 10,303 of 1906.

1063 875,580. Metallurgical method of treating oxidized zinc ores (calamines, oxides, silicates) by the precipitation process.—**Antoine H. Imbert,** Grand-Montrouge, France, assignor to Imbert Process Co., New York, N. Y. Filed June 6, 1907. Issued Dec. 31, 1907.

The process of extracting zinc from oxide ores, which consists in heating the ore in the presence of a metallic oxide, a metallic sulphide of such a character as to form a dissolvent for said ores and a metallic reagent having a greater affinity for the element with which the zinc is combined than has the zinc. Patented also in England, No. 10,303 of 1906.

1064 876,275. Smelting furnace with oil fire.—**August Koch,** Hanover-List, Germany. Filed June 27, 1906. Issued Jan. 7, 1908.

In a furnace of the character described, the combination of a plurality of chambers adapted to be alternately used for melting and preheating, oil vaporizing and air heating chambers located between said melting chambers, so that the heat radiated by the melting chambers will vaporize the oil and preheat the air in said air and oil chambers.

1065 877,114. Method of obtaining oxide fumes from ores and furnace products.—**Hermann Pape,** Hamburg, Germany. Filed Dec. 31, 1906. Issued January 21, 1908.

A method of obtaining oxide fumes from ores or furnace products, consisting in finely disintegrating said ore or furnace products, in mixing finely disintegrated carboniferous reducing means therewith, in making briquets of the mixture thus obtained, in feeding said briquets continuously into a furnace, in burning the carbon contained in said briquets in said furnace, in continuously supplying a powerful current of air to said burning briquets, whereby the volatile metals contained in said ore or furnace products are first reduced and then burned to oxides in the excess oxygen of the current of air, in continuously withdrawing said oxides with the furnace gases and in continuously removing the non-volatile residue of said briquets in a liquid state from the furnace.

1066 879,482. Metallurgy of zinc.—**Franz Meyer,** Engelwood, N. J., assignor to Metallurgical Company of America, New York, N. Y. Filed Jan. 13, 1906. Issued Feb. 18, 1908.

The method of treating ore or the like in an internally heated furnace, which consists in feeding the charge containing the ore in an upward direction through the active zone or zones of the furnace, progressively supplying from below fresh portions of the charge, causing the air necessary for combustion to traverse the active zone or zones in a downward direction, withdrawing the products of combustion and reaction laterally from the moving charge, condensing out any distilled or vaporized metal contained in said products, at their point of issuance from the charge, and maintaining the temperature of the condensed metal above its melting point so as to permit its collection in a liquid state. 7 claims.

1067 879,483. Metallurgical furnace.—**Frank Meyer,** Englewood, N. J., assignor to Metallurgical Company of America, New York, N. Y. Filed Jan. 13, 1906. Issued Feb. 18, 1908.

1068 881,355. Process of treating zinc-retort residues.—**Gustav Stolzenwald,** Valca Calugareasca, Roumania. Filed Sept. 22, 1906. Issued March 10, 1908.

A process of utilizing waste products of zinc works consisting in mixing material containing zinc with the residue from zinc distillation works and heating said mixture in a continuous acting furnace whereby the use of coal and coke is rendered unnecesary. Patented also in England, No. 18,134 of 1906; in France, No. 368,458.

1069 893,415. Process of refining zinc.—**Richard Ziesing,** Cleveland, Ohio. Filed Feb. 27, 1907. Issued July 14, 1908.

The process of refining zinc from an alloy containing lead, which consists in directing heat from above against the receptacle containing the zinc-lead alloy, sufficient to maintain the body of metal in a freely molten or fluid condition and meanwhile insure surface distillation of the zinc, whereby the lead settles to the bottom of the receptacle and the zinc is vaporized, and shielding the lower portion of the receptacle containing the lead, from heat.

1070 893,560. Apparatus for refining zinc.—**Richard Ziesing,** Cleveland, Ohio. Filed Feb. 27, 1907. Issued July 14, 1908.

1071 894,383. Treatment of ores by means of the precipitation process.—**Antoine H. Imbert,** Grand-Montrouge, France, assignor to Imbert Process Company, New York, N. Y. Filed Aug. 19, 1907. Issued July 28, 1908.

The smelting of zinc ores by the precipitation process, consisting in introducing into a hermetically closed chamber a continuous current of liquid superheated metal of a character capable of replacing the metal of the ore which it is desired to extract, introducing a charge of crushed ore and dissolvents in the form of a stream, causing the two streams to meet and allowing them to flow along in contact until the zinc be exhausted, collecting separately the zinc vapors and gaseous products in condensing the zinc, causing the excess of metal to escape separately and in causing it to return to the superheater and then to the reacting chamber, causing the residue of the reaction with the gangues to escape by a trapped orifice, and recuperating the reacting metal contained in such residues and returning it to the superheater. 7 claims. Patented also in England, No. 16,834 of 1907.

1072 899,322. Process of treating complex ores containing zinc and other volatilizable metals for the production of oxides.—**George M. Rice,** Worcester, Mass. Filed July 25, 1907. Issued September 22, 1908.

The process of producing zinc oxide from sulphide ores. which consists in mixing with the crushed raw ore finely divided particles or chips of metallic iron in quantity sufficient to overbalance the sulphur requirements, and also sufficient to form a slag with the silica contained in the ore, charging such mixed ore and iron particles into a melting furnace and subjecting the same to heat, thereby vaporizing the volatile metals and melting the matte and slag residuals, oxidizing the metallic vapors as they pass off from the charge, and then condensing and collecting the oxidized product.

1073 900,845. Gas-furnace.—**Louis G. Fromont,** Liege, Belgium. Filed April 6, 1905. Issued Oct. 18, 1908.

"The claim is for special modes of arranging the burners and crucibles and directing the gas or flame currents, particularly in furnaces for the distillation of zinc, with a view to economize labor." —J. S. C. I. Patented also in France, No. 353,462.

1074 901,405. Smelting-furnace.—**George A. Wettengel,** St. Louis, Mo. Filed Aug. 13, 1907. Issued Oct. 20, 1908. 9 claims. Patented also in Germany, no 224,457.

1075 902,534. Metallurgical condenser.—**Woolsey M. Johnson,** Hartford, Conn. Filed Jan. 8, 1908. Issued October 27, 1908. 17 claims.

1076 902,535. Method of condensing volatile metals.—**Woolsey M. Johnson,** Hartford, Conn. Filed Jan. 8, 1908. Issued October 27, 1908.

The method of condensing volatile metals which consists in bringing metallic vapors into contact with a body of molten metal and regulating the mass of the molten metal in contact with the vapors to secure substantially complete condensation of said vapors. 18 claims.

1077 905,280. Metallurgical process.—**Anson G. Betts,** Troy, N. Y. Filed Feb. 19, 1908. Issued Dec. 1, 1908.

The process of recovering a metal or metals including zinc, which consists in reacting on a material containing oxidized zinc with silicon. 11 claims.

1078 905,753. Process of extracting zinc.—**Edward H. Shortman,** Bloxwich, Eng., assignor of one-half to the New Delaville Spelter Co., Ltd., Spring Hill, Eng. Filed Dec. 13, 1907. Issued Dec. 1, 1908.

The improvement in the art of separating lead and zinc vapors in the extracting of zinc by distillation which consists in passing the metallic vapors prior to condensation through a lead-intercepting medium which separates the lead by a mechanical or physical action, the said medium being used until its lead-intercepting properties are impaired, and then displacing said intercepting medium into the retort and continuing the zinc-condensing process without interruption but without providing for the interception of the lead. Patented also in England, No. 7,223 of 1907 and No. 7,223a of 1907.

1079 906,191. Reduction of zinc oxides.—**Pierre-Armand Brangier,** Agnew, and **John J. Faulkner,** Berkeley, Cay. Filed May 29, 1907. Issued Dec. 8, 1908.

The process for producing metallic zinc said process consisting in heating the oxide of zinc to a volatilizing temperature then mixing therewith a body of hydrocarbon gas or vapor transferring the volatilized zinc to a chamber where the temperature is reduced to the point of fluidity of the zinc.

1080 907,416. Apparatus for extracting zinc.—**Edward H. Shortman,** Bloxwich, England, assignor of one-half to The New Delaville Spelter Company, Ltd., Spring Hill, Birmingham, England. Filed Sept. 17, 1908. Issued December 22, 1908.

Filter for lead fumes.

1081 914,339. Means for charging the retorts of zinc and other analogous furnaces.—**Emile DorDelattre,** Liege, Belgium. Filed July 1, 1908. March 2, 1909.

Patented also in England, No. 13,822 of 1908.

1082 914,839. Apparatus for use in smelting zinc ore, galvanizer's dross and the like.—**Evan H. Hopkins,** Addlestone, England. Filed Oct. 3, 1908. Issued March 9, 1909.

The combination with a zinc retort condenser, of a tube containing broken coke or charcoal, inserted at the mouth of the condenser. Patented in England, No. 25,099 of 1907.

1083 916,487. Ore reducing furnace.—**George F. Rendall,** New York, N. Y., assignor to American Reduction Company. Filed Nov. 20, 1906. Issued March 30, 1909.

A furnace for calcining ores having a chamber for heating the ore, a gas holder, and means connected therewith for admitting gas thereto without danger of combustion in said holder. 7 claims.

1084 919,375. Method of recovering zinc compounds and ammonia.—**Elias G. Pearlman** and **Martin M. Pearlman,** Philadelphia, Pa. Filed Oct. 3, 1908. Issued April 27, 1909.

The method of recovering zinc compounds and ammonia, which consists in roasting or smelting sal-ammoniac-fluxes or skimmings, by-products of the galvanizing process, acting on the gases and fumes given off first with steam then with an alkaline solution and finally treating the remaining gases with an acid solution.

1085 919,376. Apparatus for recovering zinc compounds and ammonia.—**Elias G. Pearlman** and **Martin M. Pearlman,** Philadelphia, Pa. Filed Oct. 6, 1908. Issued April 27, 1909.

A roasting or smelting furnace having a stack with a closed top and side conduit, a vessel for containing a solution, pipe connections from said conduit with said vessel, said pipe connections extending into and from said vessel to a tank having an escape pipe, and an injector device connected with the pipe connections from said conduit with said vessel.

1086 920,336. Method of manufacturing zinc oxide.—**Louis. S. Hughes,** Joplin, Mo., assignor to Picher Lead Co. Filed Nov. 13, 1906. Issued May 4, 1909.

The method of manufacturing zinc oxide from zinc sulphide which consists in finely dividing the zinc sulphide ore or compound, heating a furnace by an internal gas flame to a temperature at which the zinc sulphide in admixture with air will be decomposed and zinc oxide formed, feeding the ore to the heated portion of the furnace by means of an air jet, separating the zinc oxide and furnace gases from impurities by subsidence and separating the zinc oxide from the gases by screening.

1087 920,337. Method of making zinc oxide.—**Louis S. Hughes,** Joplin, Missouri., assignor to Picher Lead Company. Filed Nov. 13, 1906. Issued May 4, 1909.

The method of manufacturing zinc oxide from zinc carbonate which consists in finely dividing the carbonate, maintaining a furnace at an internal temperature sufficient to decompose the carbonate by an internal gas flame, injecting the finely divided carbonate into the heated portions of the furnace to decompose it, separating the zinc oxide and furnace gases from impurities by subsidence and separating the zinc oxide from the gases by screening.

1088 921,375. Means for protecting operatives of zinc and anologous furnaces from heat, fumes, and dust.—**Emile Dor-Delattre,** Liege, Belgium. Filed Aug. 12, 1908. Issued May 11, 1909.

1089 922,906. Revolving furnace for volatizing ores.—**Harry H. Hughes,** Springfield, Mo. Filed April 5, 1909. Issued May 25, 1909.

1090 927,857. Process of reducing zinc ores.—**Antoine H. Imbert,** Grand-Montrouge, France, assignor to Imbert Process Company, New York, N. Y. Filed Sept. 8, 1908. Issued July 13, 1909.

The process of reducing sulphide ores consisting in melting a mixture of the ore and peroxide of iron and treating the molten mixture with a reactive metal. 9 claims.

1091 932,279. Furnace for volatile metals.—**Woldemar Hommel,** London, England, assignor to Metals Extraction Corporation. Filed Nov. 30, 1908. Issued Aug. 24, 1909.

1092 936,245. Apparatus for filling zinc-retorts with granular material.—**John D. James,** Pulaski, Va. Fined Nov. 12, 1906. Issued Oct. 5, 1909. 6 claims.

1093 947,831. Manufacture of zinc.—**Oscar Loiseau,** Sclaigneaux, Belgium. Filed June 17, 1908. Issued February 1, 1910.

A mixture of oxidized ore and carbon is subjected to the direct reducing action of carbon monoxide in a practically pure state, not mixed with nitrogen, at the temperature required for the reduction of the zinc.

1094 948,740. Process for obtaining zinc from zinciferous materials.—**Herman Pape,** Hamburg-Billwärder, Germany. Filed Sept. 30, 1909. Issued Feb. 8, 1910.

Consists in feeding into a smelting furnace a charge of small fuel, briquets composed of pulverized zinciferous materials and a reducing agent, and finally lumps of zinciferous material, followed at predetermined intervals by a series of such charges superposed one on top of another.

1095 953,405. Smelting furnace.—**Charles A. Wettengel,** Caney, Kans., assignor to American Zinc, Lead and Smelting Company, Boston, Mass. Filed July 22, 1909. Issued March 29, 1910. 7 claims.

1096 958,150. Regenerative furnace.—**Frank Meyer,** Englewood, N. J., assignor to Metallurgical Company of America, New York. Filed October 24, 1905. Issued May 17, 1910.

1097 959,924. Smelting process.—**Edward Dedolph,** Kaslo, British Columbia, Canada. Filed November 4, 1909. Issued May 31, 1910.

The continuous process of extracting lead or zinc or both from their ores or slag as oxide in the form of fume, which consists in continuously supplying the material mixed with fuel, to an inclosed chamber, causing the material to travel slowly along the bottom of said chamber, admitting flame and air to the chamber, the flame being admitted at a region remote from the region where the material is admitted to the chamber, continuously liberating the metal as oxide in the form of fume and carrying off and collecting the fume thus formed, and continuously removing the residue from the chamber. Patented also in France, No. 421,910.

1098 963,416. Extraction of zinc.—**Charles Brand,** Troon, Scotland, assignor to Brand's Pure Spelter Company, Ltd., Glasgow, Scotland. Filed Feb. 16, 1910. Issued July 5, 1910.

A furnace heated retort furnished with a filter, comprising a container, a charge of refractory material within the container, the container approximately filling the bore of the retort and being situated entirely within the retort at a place to ward the front thereof, where the retort is directly heated by the furnace. Patented also in England, No. 9,955 of 1909; in France, No. 412,842.

1099 969,254. Apparatus for charging the retorts of zinc and other analogous furnaces.—**Emile DorDelattre,** Liege, Belgium. Filed May 6, 1910. Issued September 6, 1910.

1100 974,257. Metal-reducing process.—**Frederick W. Gordon,** Philadelphia. Filed Sept. 25, 1908. Issued November 1, 1910.

That improvement in the art of reducing the ores of volatile metals and recovering the metal therefrom which comprises the following steps, viz: establishing and maintaining a columnar furnace-charge comprising commingled ore and fuel; establishing and maintaining therethrough an upward current represented by air injected at the base of the column and by gases discharged at the top of the column; establishing and maintaining within the column two successive zones, a lower one of reduction and gasification and metal vaporization and an upper one of metal-vapor condensation; withdrawing from between said zones some of the furnace gases with their quota of metal vapor; condensing a portion of the metal vapor contained in said withdrawn gases; and recovering the metal resulting from said condensation. 8 claims. See also item 873.

1101 975,217. Treatment of zinc ores by the precipitation process.—**Adolphe Desgraz,** Hanover, Germany, assignor to Imbert Process Company, New York. Filed Dec. 6, 1909. Issued November 8, 1910.

A process for the extraction of zinc from zinc sulphide ores which consists in employing lead slag as a dissolvent for the ore and subsequently precipitating the zinc by a reacting metal (iron) having a greater affinity for sulphur than has zinc. Patented also in France, No. 407,305.

1102 976,557. Process of producing metallic zinc.—**Oliver B. Dawson,** El Paso, Tex. Filed March 16, 1909. Issued Nov. 22, 1910.

Consists in introducing into the zinc vapors at or above the zone of combustion carbon monoxide in sufficient quantity to combine with any unconsumed particles of oxygen.

1103 980,640. Furnace for volatizing zinc from its ores.—**Harry H. Hughes**, Springfield, Mo., assignor of one-half to F. X. Heer and A. J. Eisenmayer, Springfield, Mo. Filed Feb. 11, 1910. Issued January 3, 1911. 12 claims. Patented also in England, no. 570 of 1911; in France, no. 425,341.

1104 980,641. Method of treating zinc ores for the recovery of metallic zinc therefrom.—**Harry H. Hughes**, Springfield, Mo. Filed April 6, 1910. Issued Jan. 3, 1911.

The continuous method of volatilizing metallic zinc from its ores, consisting in introducing the ores into a heated retort, agitating the ores while contained within the retort, passing the volatilized metal and residue from the retort into a condensing chamber, permitting the escape of the condensed metal from the condensing chamber, and removing the residue from the condensing chamber.

1105 993,019. Manufacture of zinc oxide.—**Abraham Blum,** Monterey, Mexico. Filed Oct. 17, 1910. Issued May 23, 1911.

The method of making zinc oxide from zinciferous materials, such as calcined zinc ore, crude ore, and the like, which consists in establishing a charge made up of a plurality of layers of zinciferous material mixed with crushed fuel for reduction, alternating with a plurality of layers of crushed fuel constituting auxiliary heating zones therefor, blasting the charge with air, and recovering the resultant zinc oxide fumes. 9 claims. Patented also in England, No. 29,485 of 1910; in France, No. 424,380. See also item 912.

1106 993,513. Means for withdrawing dust and fumes from zinc or similar furnaces.—**Em'le Dor Delattre,** Liege. Filed June 19, 1908. Issued May 30, 1911.

The combination with a zinc or similar furnace having two vertically separated passages, the upper one arranged to receive fumes generated in the furnace and the other communicating with the chamber of the furnace wherein relatively heavy solid particles of dust from the retorts crucibles, etc., collect, of a stack or chimney communicating with both said passages, and a flue arranged within the stack and adapted to receive the highly heated gases escaping from the combustion chamber of the furnace, the heights and diameters of the stack and flue being so proportioned that a large volume of air is caused to move rapidly through the space separating them and effectually carry off both the fumes and the relatively heavy dust produced by operating the furnace. Patented also in France, No. 391,513.

1107 1,002,037. Metallurgy of Zinc.—**Frank L. Clerc,** Boulder, Colo. Filed Apr. 24, 1911. Issued Aug. 29, 1911.

The method of reducing zinc oxide by carbon and recovering the resulting zinc vapors, which consists in establishing a trapped body of molten metal in the bottom of a retort, said trapped body of metal terminating the outside of the retort in an outer well, supplying a charge of zinc oxide and carbon to the surface of the trapped portion within the retort, heating the metal in the outer well, and reducing the zinc oxide of the charge by the carbon, by means of heat conducted from the well through said molten metal to the surface of the portion trapped within the retort. See also 1,012,816.

—Described in Met. & Chem. Eng., vol. 9, p. 609. Nov., 1911.

1108 1,003,051. Process for the treatment of sulphureted copper-zinc ores in a converter.—**Desire Korda,** Paris, France, assignor to Société Comerciale des Mines, Minerais et Metaux, Paris. Filed August 16, 1910. Issued September 12, 1911.

The method of treating sulphureted copper and zinc ores, rich in zinc, which method consists in mixing said ore with coke in small pieces, melting said mixture in a converter formed with an interior lining containing a high proportion of coke, injecting compressed air into said molten metal, and prior to swinging the converter adding to the molten mass a small quantity of pyrites containing very little copper and zinc. Patented also in France, No. 430,159.

1109 1,007,124. Manufacture of oxide of zinc for smelting.—**Ralph MacIvor** and **Waldemar Hommel,** London, England, assignors to the Metals Extraction Company, Ltd., London. Filed Aug. 22, 1910. Issued Oct. 31, 1911.

Densifying light zinc oxide by converting it into oxychloride which sets, and expelling the zinc chloride therefrom by heat, thus leaving zinc oxide of increased specific gravity. Patented also in England, No. 19,386 of 1909.

—Described in Met. & Chem. Eng., vol. 10, p. 51. Jan., 1912.

1110 1,007,990. Method or process for the reduction and smelting of ore and arrangement therefor.—**Filip Tharaldsen,** Trondhjem, Norway. Filed May 31, 1911. Issued November 7, 1911.

Method of reducing and smelting ores, which consists in feeding a charge consisting principally of ore into the top of a suitable furnace, supplying charges of solid material comprising a reducing agent to said first named charge during the passage of the latter through the furnace at points near the melting zone, so as to control the proportions of ore and reducing agent required in the charge toward and within the melting zone, and at the same time feeding in said charge comprising the reducing agent so that it forms a layer on the interior side of the furnace which forms an envelope entirely surrounding or inclosing the central charge consisting principally of ore. 10 claims.

1111 1,009,863. Furnace for extracting zinc.—**Otto Schneemilch,** Wilhelminhütte, near Schoppinitz, Germany. Filed July 28, 1911. Issued Nov. 28, 1911.

A furnace for extracting zinc ores comprising a chamber to which hot gases are admitted, vertical retorts passing their whole length freely through said chamber so as to be uniformly surrounded by the hot gases over their whole length and means whereby said retorts may be removed from below said chamber. 6 claims. Patented also in England, No. 18,003 of 1911.

1112 1,012,816. Metallurgy of zinc.—**Frank Clerc,** Boulder, Colo. Filed November 4, 1911. Issued December 26, 1911.

Apparatus for reducing zinc oxide by carbon, comprising a plurality of retorts closed at bottom by a trapped body of substantially quiescent molten metal terminating in a well exterior to the retorts, a continuous heating chamber inclosing the common well, and means for directing fuel in combustion across the upper surface of the metal in the well. See also 1,002,037.

—Described. Met. & Chem. Eng., vol. 10, p. 556. Sept., 1912.

1113 1,014,062. Method of producing zinc oxide.—**Harry H. Hughes,** St. Louis, Mo. Filed May 27, 1911. Issued January 9, 1912.

The continuous process of producing zinc oxide from sulphide and other sulphur bearing ore consisting in roasting the ore to eliminate practically all of the sulphur in the form of fumes, delivering the roasted ore while still in a heated condition into a rotary reduction furnace, the interior of which is heated solely by the combustion of liquid or gaseous hydrocarbon within said furnace, causing the heated ore to pass through the furnace, and introducing air into said furnace to reduce the zinc vapor to an oxide.

—Described. Met. & Chem. Eng., vol. 10, p. 179. Mar., 1912.

1114 1,014,333. Mechanical device for charging and cleaning zinc retorts.—**Otto Saeger.** Issued Jan. 9, 1912.

—Described in Met. & Chem. Eng., vol. 10, p. 179. Mar., 1912.

1115 1,030,676. Zinc distillation.—**John Moulden** and **Harold Webster,** Seaton Carew, England, assignors to Central Zinc Company, Ltd. Seaton Carew, England. Filed Dec. 29, 1910. Issued June 25, 1912.

The step in the process of zinc distillation which consists in bringing into contact with retort vapors a haloid salt to prevent the formation of zinc oxide. 9 claims. Patented also in England, No. 5,196 of 1911; in France, No. 423,912.

1116 1,038,205. Preheater for zinc furnaces.—**Carl Roitzheim,** Germany. Issued Sept. 10, 1912.

—Described in Met. & Chem. Eng., vol. 10, p. 697, Oct., 1912.

1117 1,041,977. Zinc-retort-furnace.—**Charles A. H. De Saulles,** Gas, Kansas, assignor to New Jersey Zinc Company, New York. Filed April 22, 1911. Issued October 22, 1912.

A zinc retort furnace provided with a combustion chamber having an exit flue for the products of combustion at one end thereof, zinc retorts located within the chamber, a series of air ports and a series of gas ports opening into the combustion chamber below the retorts, an air pressure main and a gas pressure main communicating with the said air and gas ports respectively, and valves for controlling independently the air supply and the gas supply from the mains to each of the air and gas ports.

—Described, with diagr., in Met. & Chem. Eng., vol. 10, p. 816. Dec., 1912.

1118 1,047,360. Process of separating zinc and lead from mixed sulphides.—**Carl L. W. Witter,** Hamburg, Germany. Filed Nov. 8, 1909. Issued Dec. 17, 1912.

Comprises comminuting the ores, subjecting them to oxidizing roasting to eliminate the greater part of their sulphur content, briqueting the ore with a reducing agent and a binder, charging the briquets so formed into a suitable furnace in the presence of a non-oxidizing atmosphere and substantially out of contact with the flame of the furnace and on a fluid slag under-lay sufficiently thick to maintain a substantially uniform temperature within the furnace, thereby reducing and evaporating the zinc, oxidizing and cooling the zinc vapors, and recovering the zinc as oxide of zinc. 7 claims. Patented also in France, No. 408,612. See also item 923.

1119 1,048,420. Zinc-furnace.—**George Londress** and **Webster Worley,** Grafton, W. Va. Filed June 25, 1912. Issued Dec. 24, 1912.

A furnace comprising front and rear buck-stays, interlocking connecting members between the front buck-stays to maintain the latter in spaced relation, each of the interlocking members having a recess therein, and fire brick material in the recesses of said members to protect the same from heat and flame and adapted to form retort supports. 15 claims. Patented also in England, No. 11,900 of 1913.

1120 1,048,603. Hydro-electric smelting-furnace.—**Antonio Tommasini,** New York, N. Y., assignor of one-half to Marcellus E. Thornton, Hickory, N. C. Filed Aug. 1, 1912. Issued Dec. 31, 1912.

In a smelting furnace, the combination of a reheater or crucible, and electrically heated hydrogen supplying furnace in communication therewith, a rotatably mounted tubular hearth in communication with the reheater, a charging means for supplying ore to the hearth, and a hydrogen retriever in communication with the charging end of the hearth.

1121 1,049,569. Gas-furnace.—**Alexander Folliet,** Brussels, Belgium. Filed July 20, 1911. Issued January 7, 1913. 10 claims.

1122 1,049,570. Zinc furnace.—**Alexandre Folliet,** Brussels, Belgium. Filed Sept. 21, 1911. Issued January 7, 1913. 12 claims. Patented also in England, no.. 2,250 of 1911; in France, no. 430,942.

1123 1,049,746. Process of treating metal and mineral bearing materials.—**John L. Malm,** Denver. Filed August 9, 1909. Issued January 7, 1913.

The process of treating ore which consists in subjecting the same in a suitable receptacle to the action of a salts-forming gas for a sufficient length of time to form the salts of only part of the metal or metals, and introducing a cooling agent with the halogen gas in the receptacle. 21 claims.

1124 1,051,512. Ore-reducing furnace.—**Peter Evert Peterson,** Butte, Mont. Filed May 10, 1912. Issued January 28, 1913.

1125 1,059,307. Apparatus for the manufacture of metallic zinc. **Robert Denis Lance,** La Garenne-Colombes, France, assignor to Pierre Ferrere, Paris, France. Filed Feb. 26, 1913. Issued April 15, 1913.

In an apparatus for manufacturing zinc, a retort, a central heating chamber therefor, the ends of the retort being extended through the walls of said central heating chamber, an inverted bottle shaped member disposed outside of said central heating chamber, a conduit connecting said retort with said bottle shaped member, a collector arranged to receive the open end of said bottle-shaped member, and means for regulating the temperature of said conduit, said bottle-shaped member, and said collector.

1126 1,069,085. Process of recovering zinc and other volatile metals.—**Thomas Huntington,** London, England, and **Ferdinand Heberlein,** Frankfort-on-the-Main, Germany. Filed Oct. 25, 1910. Issued July 29, 1913.

Consists in charging a comparatively thick layer of the ore or other material mixed with reducing fuel in a suitable furnace, igniting the charge at the top, forcing an air current downward through the charge, thereby generating within the body of the charge the combustion gases relied upon for heating, decomposing and reducing, decomposing and reducing by said downward escaping combustion gases the compounds of the charge which may be injurious to the subsequent production of metallic vapors, reducing the oxidizing constituents of the gas current by the incandescent fuel, distilling the volatile metals out of the charge, condensing the metallic vapors, sintering substantially the entire residues and discharging the sintered mass for preparing the furnace to receive a fresh charge. 9 claims. Patented also in England, No. 20,896 of 1910, No. 8,035 of 1911; in France, No. 435,143.

1127 1,072,209. Process of extracting zinc from residues containing zinc, especially slags, in reverberatory furnaces.—**Adolphe Henri Desgraz,** Hanover, Germany. Filed July 31, 1911. Issued September 2, 1913.

The process of recovering easily reducible and volatile metal from substances containing the same, which consists in forming such substances to a molten liquid bath of slag, and reacting upon said molten bath with a suitable basic agent, (calcium oxide) thereby driving off said metal from the bath. 6 claims. Patented also in Germany, No. 248,179.

—Described in Met. & Chem. Eng., vol. 11, p. 656. Nov., 1913.

1128 1,073,461. Process for the separation of lead and zinc.—**Jules Babe,** Honfleur, France. Filed April 4, 1911. Issued September 16, 1913.

A process for the separation of lead and zinc contained in mixtures or combinations of salts or oxides of these metals, which consists in sulphureting the lead in the presence of a volatile reducing agent at a temperature below that at which the zinc is affected. Patented also in France, No. 428,707.

1129 1,080,102. Process of reducing zinc compounds.—**Elisha B. Cutten,** Erie, Pa. Filed Sept. 15, 1913. Issued Dec. 2, 1913.

The process of reducing zinc compounds free from slag forming materials which consists in subjecting them in the absence of fluxing material but in the presence of carbon to a temperature ordinarily sufficient to vaporize metallic zinc, and under a pressure sufficiently high to prevent such vaporization, the zinc being thereby precipitated as molten metallic zinc.

1130 1,082,765. Condensation of zinc.—**Augustin L. J. Queneau,** Philadelphia, Pa. Filed April 23, 1912. Issued Dec. 30, 1913.

A condenser for zinc vapors, provided with baffle plates of carbon projecting into its interior. 14 claims.

1130a 1,082,766. Collector.—**Morley Punshon Reynolds,** Cleveland, Ohio, assignor to the W. S. Tyler Co. Filed Sept. 16, 1912. Isued Dec. 30, 1913.

1131 1,086,939. Muffle for reduction-furnaces.—**Alexander Roitzheim,** Duisburg-Ruhrort. Filed April 22, 1913. Issued Feb. 10, 1914.

A muffle for reduction furnaces, comprising a vertical casing having a gas chamber therein formed of a plurality of horizontally disposed slats, the adjacent edges of which form apertures. Patented also in England, No. 9,314 of April 21, 1913; in France, No. 456,636.

1132 1,100,490. Process for the recovery of zinc from its ores.—**Alex Roitzheim,** Düren, Germany. Filed August 28, 1911. Issued June 16, 1914.

The step in the process of zinc distillation in retorts, which comprises preheating the charge of ore and reducing material to a temperature above the condensation temperature of zinc and below the reducing temperature of the charge, (about 600° C.) thereby preventing zinc dust formation. Patented also in England. No. 19,587 of 1911.

1133 1,112,010. Treatment of zinc residues.—**Archibald Jones,** Bartlesville, Oklahoma, assignor to Bartlesville Zinc Co. Filed July 5, 1911. Issued September 29, 1914.

The method of treating zinc retort residues which consists in concentrating them by combustion of their carbon content and simultaneously volatilizing the contained zinc and catching the products of volatilization of the zinc in the outer layers of the pile. See also item 851.

1134 1,114,036. Metallurgy of zinc.—**Augustin L. J. Queneau,** Torresdale, Pa., assignor to Queneau Electric Zinc Furnace Company, Philadelphia, Pa. Filed Dec. 7, 1908. Issued October 20, 1914.

The method of extracting and recovering zinc from zinc ore, which consists in preheating said zinc ore, separately charging into a reducing furnace the ore in the preheated state and a reducing agent, intimately mixing them within the furnace, subjecting the mixture to a reducing atmosphere and a reducing temperature with exclusion of air, thereby releasing the zinc in the form of zinc vapor, and condensing said vapor to the metallic state. Patented also in France, No. 403,048.

1135 1,118,012. Process of smelting zinc ores.—**James M. Hyde,** Berkely, Cal. Filed Feb. 13, 1914. Issued Nov. 24, 1914.

The process of smelting zinciferous ores, which consists in heating the ore mixed with flux and reducing-agent in an externally heated retort to a temperature sufficient to reduce the metallic constituents, collecting the molten material in a bath beneath the charge, removing the zinc vapors from the retort above the molten bath, and keeping the bath molten by heat directly applied to the surface thereof outside said retort. 8 claims. Patented also in England, No. 2,221 of 1915; in France, No. 477,646.

1136 1,127,264 Smelting furnace.—**Edwin Vincent Lanyon** and **Frances Albert Curnow,** Pittsburg, Kansas. Filed April 11, 1914. Issued February 2, 1915. 15 claims.

1137 1,133,637. Process of preventing escape of noxious gases in smelting.—**William A. Hall,** New York. Filed June 25, 1913. Issued March 30, 1915.

In a process of smelting sulphides, the step of preventing the discharge of sulphurous gases into the atmosphere, which comprises maintaining a layer of said sulphides at the top of the charge, at a temperature below that at which sulphur will ignite, by spraying the top of the ore charge with a liquid containing water.

1138 1,136,304. Zinc-producing furnace.—**Albert Zavelberg,** Hohenlehenhütte, Germany. Filed August 25, 1914. Issued April 20, 1915.

In a zinc producing furnace the combination of a plurality of vertical, superposed rows of shafts, preheating chambers above the upper row of said shafts, a plurality of juxtaposed chambers within said shafts, walls separating said chambers, means within said walls for producing gas tight partitions between each two of said chambers, condensers in front of, and connected to the chambers of the various rows of shafts, and means for connecting the preheaters with the upper row and this upper row with the lower row of said shafts.

1139 1,137,835. Briquet for use in zinc furnaces.—**George S. Brooks,** Depue, Ill., assignor to the New Jersey Zinc Company, New York. Filed Nov. 28, 1913. Issued May 4, 1915.

A briquet for zinc furnaces, composed of zinc ore and coal surrounded by and inclosed within a protecting shell or coating containing a large percentage of common salt

1140 1,144,036. Zinc-smelting furnace.—**James M. Hyde, Berkeley,** Cal. Filed Mar. 10, 1915. Issued June 22, 1915. 11 claims.

1141 1,144,037. Method of smelting zinc and other ores.—**James M. Hyde,** Berkeley, Cal. Filed Mar. 10, 1915. Issued June 22, 1915.

The process of smelting zinciferous materials which consists in mixing with the zinciferous material a proper amount of reducing agent, charging the same into a retort while preventing the passage of vaporized zinc, through the charging device, vaporizing by external heat the zinc in the retort and separately removing the vaporized zinc and the solid residues from the retort while continuing the smelting operation, and preventing the passage of gas out of or into the retort through the opening through which the residues are withdrawn.

1142 1,144,066. Process and apparatus for removing drossy residues from vertical muffles in the extraction of zinc.—**Alexander Roitzheim,** Duisburg, Germany. Filed Sept. 22, 1913. Issued June 22, 1915.

1143 1,144,065. Mechanism for removing residues from vertical retorts.—**Alexander Roitzheim** and **Wilhelm Remy,** Duisburg, Germany. Filed Dec. 20, 1912. Issued June 22, 1915.

1144 1,145,685. Condenser for zinc and lead vapors.—**Edwin Andreas Johansson,** Trollhättan, Sweden. Filed April 21, 1915. Issued July 6, 1915.

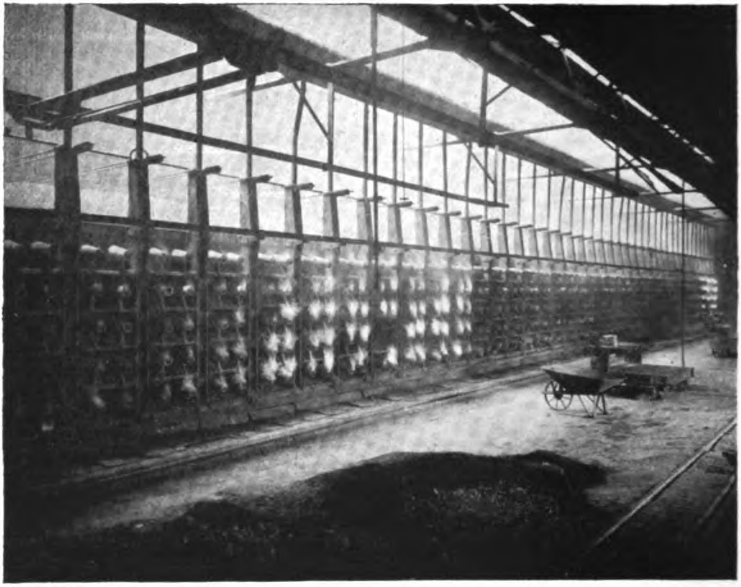
A condenser having a loose bottom and means for rotating said bottom.

1145 1,152,050. Arrangement for preventing the formation of smoke in the production of zinc.—**Alexander Roitzheim,** Duisburg-Ruhrort, Germany. Filed April 1, 1913. Issued Aug. 31, 1915.

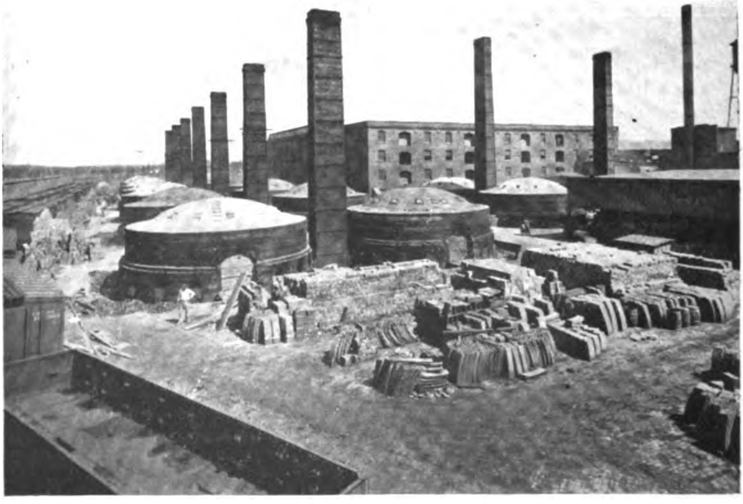
Patented also in England, No. 6,771 of 1913; in France, No. 455,726.

1146 1,153,203. Method of treating ores.—**Louis C. Drefahl,** Cleveland, Ohio, assignor to The Grasselli Chemical Company, Cleveland. Filed April 15, 1914. Issued September 14, 1915.

The method of conditioning fine or dusty ore material for further treatment, which consists in forming such material into a plastic mass; dividing up such mass into relatively small nodules; and then



ZINC RETORTS, HILLSBORO SMELTER,
American Zinc, Lead & Smelting Co.



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maintaining such nodules relatively stationary and simultaneously subjecting the same to heat sufficient to dry and harden but not otherwise affect the same.

1147 1,155,628. Method for the treatment of zinc or zinc-bearing material.—**Sewall Truax,** Canon City, Colo., assignor to Granadena Mining Company. Filed Dec. 16, 1910. Issued Oct. 5, 1915.

The method of treating slag containing zinc comprising maintaining the slag in a fluid condition in contact with a body of finely divided reducing material, the particles of which are prevented from passing into the fluid.

—Described in Eng. & Min. Jour., vol. 100, p. 803. Nov. 13, 1915.

1148 1,157,375. Process for the manufacture of spelter from ferruginous and admixed blende ores.—**John James Fingland,** Kaslo, British Columbia, Canada. Filed Sept. 10, 1915. Issued Oct. 19, 1915.

The steps in the process of manufacturing spelter from ferruginous and admixed lead and zinc blende ores, which consists in heating a mixture of crude ore, roasted ore and lime, thereby forming litharge, maintaining the heat treatment until the litharge has been driven off by volatilization, and subsequently continuing the heat treatment at a temperature of substantially 1500° C. until a liquid zinc calcic oxide sulphide matte is produced. 6 claims.

—Described, with flow sheet, in Min. & Sci. Press, vol. 112, p. 61. Jan. 8, 1916.

1149 1,161,885. Removing cadmium from zinc ores.—**Gilbert Rigg,** Palmerton, Pa., assignor to The New Jersey Zinc Company, New York. Filed Sept. 4, 1913. Issued Nov. 30, 1915.

See also 1,246,576, Nov. 13, 1917.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 124. Jan. 31, 1916.

1150 1,161,886. Removing cadmium from zinc ore.—**Gilbert Rigg,** Palmerton, Pa., assignor to The New Jersey Zinc Company, New York. Filed July 27, 1915. Issued Nov. 30, 1915.

—Described. Min. & Sci. Pres, vol. 112, p. 245. Feb. 12, 1916.

—Described. Met. & Chem. Eng. vol. 14, p. 220-21. Feb. 15, 1916.

1151 1,166,170. Process for the production of zinc.—**Otto Baltin,** Lipine, Germany. Filed Jan. 3, 1914. Issued Dec. 28, 1915.

A method of extracting zinc from ores consisting in enclosing in a space rounded briquets formed of ore and a reducing agent, having adjacent briquets touching each other only at a single part, the combined exposed area of the briquets being a large multiple of the limited area of said space; and exposing said briquets to direct action of heat.

1152 1,166,171. Process for smelting metallic ores.—**Otto Baltin,** Lipine, Germany. Filed May 28, 1914. Issued Dec. 28, 1915.

A briquet comprising a compressed mixture of ore, gypsum and pitch.

1153 1,166,447. Zinc ore charges for retorts and method of treating the same.—**C. A. H. De Saulles,** New York. Issued Jan. 4, 1916.

The front part of a retort or muffle is fitted with a briquet of reducing agent and ore low in iron and lead, which retains these metals.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 259. Feb. 29, 1916.

—Described in Met. & Chem. Eng., vol. 14, p. 666, June 1, 1916.

1154 1,167,925. Apparatus for the extraction of zinc.—**Martin M. Pearlman,** Clarksburg, W. Va. Issued Jan. 11, 1916.

Combined filter and condenser.

—Described in Min. & Sci. Press, vol. 112, p. 484. April 1, 1916.

1155 1,168,401. Process of making briquets from zinc ores and material containing zinc.—**Otto Kippe,** Osnabrück, Germany, assignor to General Briquetting Company, New York. Filed Nov. 19, 1914. Issued January 18, 1916.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 475. Apr. 29, 1916.

—Described in Min. Wld. vol. 45, p. 246. Aug. 5, 1916.

1156 1,169,069. Desulphurizing and smelting ores.—**Arthur S. Dwight,** New York N. Y. Filed June 25 1908. Issued January 18, 1916.

The process of sintering and smelting ore initially in a fine condition, which consists in continually forming a relatively thin stream or layer of the ore, sintering said stream into a relatively strong and rigid sinter cake, at a point relatively remote from the region of smelting, continually moving the cake horizontally away from the region of the forming and sintering, projecting the forward part of the cake into the region of smelting and subjecting it to smelting action.

—Described in Jour. Soc. Chem. Ind. vol. 35, p. 314-15. Mar. 15, 1916.

1157 1,178,518. Clean-out apparatus for zinc furnaces.—**F. A. Hinkey,** Springfield, Ill. Issued Apr. 11, 1916.

1158 1,193,680. Recovery of zinc.—**Charles H. Fulton,** Cleveland, Ohio, assignor to **David B. Jones,** Chicago, Ill. Filed Dec. 24, 1914. Issued August 8, 1916.

The process of recovering zinc from zinc bearing ore, consisting in grinding and calcining the ore, mixing it with pulverized coke and a carbonaceous binder such as pitch or tar, the quantity of coke being such as to furnish the necessary carbon for reduction of all the metallic oxides in the ore, plus such an additional amount of coke that the weight of the briquet, after distillation, will not be less than forty to fifty per cent of the weight of the briquet before distillation and the quantity of binder being from twelve to fifteen per cent of the combined weight of the ore and the coke, briquetting the mixture under pressure in molds, heating the briquets to a temperature high enough to destructively distil and coke the carbonaceous binder without volatilizing the zinc-content of the ore, supporting the briquets against collapse or breaking down during such heating operation, and subsequently subjecting said briquets to the usual zinc distillation to recover the zinc. Patented also in England, No. 104,564 of 1916.

—Described. Jour. Soc. Chem. Ind. vol. 35, p. 969. Sept. 30, 1916.

1159 1,213,346. Retort apparatus.—**Edward Fink,** Milwaukee, Wis. Filed May 9, 1914. Issued January 23, 1917.

1160 1,213,347. Retort apparatus.—**Edward Fink,** Milwaukee, Wis. Filed May 9, 1914. Issued January 23, 1917.

1161 1,215,006. Method of treating zinc-bearing materials.—**Charles A. H. De Saulles,** New York, N. Y. Filed June 19, 1915. Issued Feb. 6, 1917.

The method consisting in charging a retort with molten zinc bearing material, heating the charge to approximately 1350 degrees centigrade; and then permitting the zinc vapor to rapidly expand at a relatively low temperature to form blue powder.

1162 1,215,007. Apparatus for treating zinc-bearing material.—**Charles A. H. De Saulles,** New York, N. Y. Filed June 28, 1915. Issued Feb. 6, 1917.

A retort having a vapor discharge opening and provided at one end with a closure having a feed opening, the closure below said feed opening being provided with an opening for the discharge of molten material and means for feeding molten material into the retort through said feed opening.

1163 1,221,045. Condenser for redistilling spelter.—**John G. Granberg,** Beckemeyer, Ills. Filed Dec. 8, 1916. Issued April 3, 1917.

1164 1,222,636. Smelting furnace.—**John Kirby,** Leechburg, Pa. Filed Dec. 13, 1916. Issued April 17, 1917.

1165 1,223,738. Smelting furnace.—**Edwin Ruck,** Swansea, Wales. Filed May 6, 1916. Issued April 24, 1917.

1166 1,224,057. Method of recovering zinc and iron from solutions therof.—**Charles E. Baker,** Chicago Ills. Filed Jan. 26, 1917. Issued April 24, 1917.

A method of recovering zinc and iron from solutions containing the same, consisting in simultaneously precipitating the said metals in the form of a non-compact deposit, then effecting a separation of the metals by vaporizing the zinc, and recovering the zinc.

1167 1,227,050. Zinc smelting furnace.—**Julius W. Hegeler,** Danville, and **Herman Hegeler,** deceased, Danville, Ills., by **Louise Hegeler,** executrix, assignors to the Hegeler Zinc Company, Danville, Ills. Filed Nov. 17, 1913. Issued May 22, 1917.

1168 1,231,083. Process of producing pure zinc.—**Heinrich|Speckter,** Griesheim-on-the-Main, Germany. Filed Sept. 2, 1913. Issued June 26, 1917.

The method of producing zinc from zinciferous materials which consists in mixing the zinciferous materials with carbonaceous material, then heating the mixture in the form of separate charges by direct heat and with agitation to such a degree as to cause the reduction of the impurities (such as, for instance, cadmium oxide and the like), together with volatilization of the reduction products thus freed, and then proceeding to the reduction of the zinc compounds. Patented also in England, No. 20,039 of 1913; in France, No. 461,905.

1169 1,233,652. Production of metallic zinc.—**August Joseph Francois De Bavay,** Kew, Victoria, Australia. Filed Feb. 23, 1916. Issued July 17, 1917.

A method of fractionally distilling zinc comprising passing the zinc fumes through a series of liquid zinc bubbling chambers heated respectively at substantially 900° C., 650° C., and 450° C. 9 claims. Patented also in England, No. 102,142 of 1916.

1170 1,237,141. Furnace.—**Richard Ziesing,** Cleveland, Ohio, assignor to The Grasselli Chemical Company. Filed May 4, 1916. Issued Aug. 14, 1917.

In a two-stage method of purifying zinc of heavier metals associated therewith, the steps which consist in melting the impure zinc in a chamber to allow the heavier metals to settle, drawing off the relatively pure zinc above the level of the heavier metal, distilling such drawn off metal and allowing the heavier part to drain back into such melting chamber.

1171 1,246,576. Apparatus for removing cadmium from zinc ores.—**Charles Pomeroy Fiske,** Palmerton, Pa., assignor to the New Jersey Zinc Company, New York, N. Y. Filed August 24, 1917. Issued Nov. 13, 1917.

1172 1,249,061. Process for producing spelter.—**Charles H. Fulton,** St. Louis, Mo., assignor to Metallurgical Laboratories. Chicago. Ill. Filed Jan. 22, 1917. Issued Dec. 4, 1917.

A process for manufacturing spelter which consists in forming zinc in the metallic form into objects that will retain substantially their original form and volume when subjected to zinc distillation temperatures, heating said objects to convert the metallic zinc in the same into vapor, and thereafter condensing said zinc vapor into spelter.

—Described in Met. & Chem. Eng., vol. 18, p. 539-40. May 15, 1918.

1173 1,249,960. Plastic composition and process of producing the same.—**Jefferson D. Hollingsworth** and **John Mitchem,** Kusa, Okla. Filed Jan. 4, 1917. Issued Dec. 11, 1917.

A plastic composition for use in manufacturing retorts, comprising substantially 36 pounds of fire clay, substantially 59 pounds of fire clay cement, substantially 14 pounds of graphite and substantially one pound of common salt.

—Described in Met. & Chem. Eng., vol. 18, p. 551. May 15, 1918.

1174 1,250,071. Zinc extracting furnace with vertical retorts.—**Roman Von Zelewski,** Engis, Belgium. Filed Feb. 24, 1917. Issued Dec. 11, 1917.

In a furnace of the character described the combination of a casing formed with a vertical passage, gas and air ducts formed in the casing and communicating with the vertical passage, a platform located under the vertical passage to support the vertical retort and close the bottom of the same, counter weights, guides in the casing, and cables attached to the platform and counter weights to hold the retort in the passage.

1175 1,250,261. Method of and apparatus for recovering volatile metallic values in the form of metallic oxides from molten slag.—**Herman Witteborg,** Caldwell, Idaho. Filed Mar. 6, 1917. Issued Dec. 18, 1917.

The method of recovering volatile metallic values from molten slag, which includes the steps of causing the molten slag, containing suitable reducing agent, to flow in a comparatively shallow layer, through an inclosed super-heating zone; directing a sufficiently intense naked flame and its hot gases, into positive intimate contact with the shallow layer of flowing slag, to cause the vaporization of the metallic values to be recovered; oxidizing the metallic vapors arising therefrom and finally collecting the oxidized vapors in the form of metallic oxides.

—Described in Met. & Chem. Eng., vol. 18, p. 551. May 15, 1918.

1176 1,261,342. Process for the production of zinc.—**Otto Baltin,** Lipine, Germany. Filed Feb. 25, 1914. Issued April 2, 1918.

A process for the treatment of zinc ores which consists in adding naphthalene to a mixture of the zinc ore and reducing agents; and briquetting the material.

1176a 1,269,110. Continuous process for recovering lead or zinc or both metals from their ores or from slag in the form of metal fumes whereby the charge is mixed with fuel.—**Friedrich Ohlmer,** Griescheim, near Frankfort-on-the-Main, Germany. Filed September 26, 1914. Issued June 11, 1918.

The continuous process of recovering lead or zinc or both metals in the form of oxides from their ores and slags, which comprises feeding a mixture of the metalliferous material with carbonaceous fuel into a revolving furnace, heating the mixture therein in immediate contact with a heating flame to a temperature sufficient to effect the desired reduction without smelting the charge, maintaining a reducing atmosphere in the reduction zone of the furnace so as to avoid immediate reoxidation of the disengaged metal fumes in said zone, and oxidizing said fumes thereafter in an oxidizing zone.

1177 1,271,172. Cadmium-evolving process.—**Woolsey McA. Johnson,** Hartford, Conn. Filed July 30, 1914. Issued July 2, 1918.

A process for differentially reducing a cadmium-zinc bearing material; comprising obtaining the material with a considerable sulphur-content and then subjecting the said sulphur-bearing material under reducing conditions to a temperature sufficiently high to evolve cadmium vapors but too low to evolve zinc vapors.

1178 1,271,560. Apparatus and method for condensing zinc vapor.—**Charles H. Fulton,** St. Louis, Mo., assignor to Metallurgical laboratories, Inc., Chicago, Ill. Filed Jan. 8, 1917. Issued July 9, 1918.

A zinc condenser provided with tubular shaped members arranged one within the other and spaced apart so as to form a passageway through which a gas stream from a zinc distilling apparatus travels. 22 claims.

1179 1,274,249. Process of treating zinc.—**Charles A. H. De Saules,** New York, N. Y. Filed November 3, 1915. Issued July 30, 1918.

The process of treating metallic zinc consisting in first melting zinc containing lead, and eliminating by gravity therefrom a large amount of the lead; then heating to volatilization the zinc thus treated, and thereby eliminating therefrom most of the lead which remains; then condensing to a molten condition the zinc thus volatilized; and then collecting the zinc thus condensed and retaining it in a molten condition until a relatively large body thereof has been amassed. 9 claims.

1180 1,274,120. Retort-charging machine.—**George W. Whipple** and **Cloise H. Baldwin,** Cherryvale, Kans., assignors to Edgar Zinc Company. Filed June 7, 1917. Issued July 30, 1918. 11 claims.

1180a 1,275,045. Process for utilizing the residues obtained in the distillation of zinc.—**Rudolf Koehler** and **Otto Baltin,** Lipine, Germany. Filed Jan. 3, 1914. Issued August 6, 1918.

A process for utilizing the residue of zinc distillation, said process comprising placing a new charge of zinc ore above a glowing residue of a previous charge in which residue some of the flux remains; heating and reducing the new charge from the residue by passing a strong blast through the residue and thence through the new charge; and heating and distilling the new charge, and condensing the vapors thereof, while shut off from the drafts of gas.

1180b 1,279,292. Apparatus for treating zinc.—**Charles A. H. De Saulles,** New York. Filed July 10, 1917. Issued September 17, 1918.

In an apparatus for treating zinc, a melting furnace provided with means which permit separation of lead from zinc by gravitation, a distilling furnace provided with means by which molten zinc from the melting furnace may be fed therein and provided with a plurality of condensers into which the distilled zinc is discharged and condensed to liquid, and a mixing furnace provided with means for receiving molten zinc from the condensers.

1180c 1,280,593. Furnace for treating zinc.—**Leopold Van Gulck,** Uplands, Swansea, Wales. Filed July 21, 1917. Issued October 1, 1918. Patented also in England, No. 113,393 of 1917.

1180d 1,282,847. Zinc retort furnace.—**Archibald Jones,** Langeloth, Pa., assignor to Metallurgical Company of America, New York, a corporation of New Jersey. Filed Jan. 4, 1916. Issued October 29, 1918. 7 claims.

1180c 1,287,949. Refining of zinc.—**Guy Carey Fricker,** Luton, Eng. Filed Jan. 27, 1917. Issued Dec. 17, 1918.

The method of obtaining high grade zinc from an impure grade of zinc which consists in causing the zinc produced by heating a charge of impure zinc to pass through a filter of inert material, arranged above, floating upon and completely covering the molten charge of impure zinc so that the zinc vapor is constrained to pass upward wholly through said filter and condensing the resulting purified zinc vapor. Patented also in England, No. 110,970 of 1916.

1180f 1,291,654. Vertical zinc furnace.—**Ferdinand Fiechtl,** Cherryvale, Kans. Filed Nov. 2, 1917. Issued Jan. 14, 1919.

1180g 1,292,330. Method of treating zinc ore.—**David B. Jones,** Chicago, Illinois. Filed June 22, 1914. Issued Jan. 21, 1919.

The method of recovering zinc oxide from zinc ore, consisting in forming the zinc ore into briquets with suitable reducing material, passing said briquets through the heating chamber of a suitable furnace in which the briquets are subjected to a sufficient degree of heat to expel their zinc content substantially in the form of metallic vapor, and supplying air to the space or chamber containing such vapor for the purpose of converting it into zinc oxide. 4 claims.

Great Britain

1181 22,694 of 1891. A novel system of regenerative gas furnace for the reduction of zinc ores.—**E. Dor.** Ampsin, Belgium.

"Duplicate kilns, built back to back and communicating with each other by passage below the retorts, are arranged with four regenerative chambers at each end at the ground level."

1181a 15,761 of 1894. Treating zinc sulphides in a blast furnace with ferric oxide, and thus producing metallic zinc direct. —**R. Biewend,** Clausthal, Germany.

—Described in Jour. Soc. Chem. Ind., vol. 14, p. 663. July 31, 1895.

1182 22,361 of 1896. Improvements in the extraction of lead, zinc, gold, silver and other metals from sulphides, refractory or other ores or mattes.—**J. Armstrong,** London.

The zinciferous material is heated with carbonate or nitrate of soda or potash, lime and carbon in a reducing atmosphere. The charge melts and separates into three layers, of which the top layer is a mixture of zinc, zinc salts and soda salts. This is further distilled. See also 16,312 of 1898.

1183 30,152 of 1896. Process of recovering zinc from zinciferous gases in the distillation and smelting of zinc.—**R. H. T. Biewend,** Clausthal, Germany.

"The zinc bearing gases are dry-filtered through condensers filled with fragments of charcoal or other porous or rough substance."

—Described in Jour. Soc. Chem. Ind., vol. 17, p. 159. Feb. 28, 1898.

1184 1,034 of 1897. Reduction of zinc blende and other ores, and recovery of lead with other metals therefrom.—**H. R. Angel,** London.

Treating zinc-lead sulphide ores in a reverberatory furnace with sulphate of soda and coal. The lead, containing most of the silver and gold is tapped out, whilst the volatile metals (zinc, etc.) are to be collected in chambers.

1185 8,990 of 1897. Improvements in or relating to the smelting of mixed minerals, ores, and the like containing lead and zinc.—**G. H. Blenkinsop,** Swansea.

Smelting zinc-lead sulphides in a blast furnace and maintaining the exit at a higher temperature than the volatilization of zinc.

1186 4,911 of 1898. Recovery of zinc from zinciferous slags or residues.—**H. E. Fry,** London, and **R. Addie,** Llansamlet.

"Zinc slags, etc., are mixed with carbonaceous matter and heated to a high temperature in a regenerative gas furnace, lined with dolomite or other basic material, and stirred with a green wood pole. The zinc is reduced, the fumes condensed, and the oxide collected." —J. S. C. I.

1187 7,964 of 1898. Method and apparatus for reducing zinc ores and other volatile metals in blast furnaces.—**A. M. G. Sebillot,** Paris.

Improvements in ordinary zinc smelting from oxide and carbonate, chiefly for the prevention of volatilization.

1188 14,523 of 1898. Improved furnace for treating sulphides containing zinc and other ores.—**H. R. Angel,** London.

"Furnace for the inventor's process of treating zinc-lead sulphides and recovering caustic soda."—E. & M. J.

1189 15,645 of 1898. Treatment of refractory sulphide ores.—**F. Ellershausen,** London.

"In smelting zinc-lead ores in a cupola or blast furnace, uses an additional exhaust sufficiently powerful to prevent any zinc accretions forming in the furnace."—J. S. C. I.

1190 16,312 of 1898. Improvements in the smelting of complex sulphide ores containing zinc and lead.—**J. Armstrong,** London. Addition to 22,361 of 1896.

1191 16,388 of 1898. Improvements in the extraction of zinc from its ores.—**J. Armstrong,** London.

Roasting, mixing with an alkali salt, with or without fluxing material, lixiviating the soluble matter, and distilling with carbon.

1192 3,475 of 1899. Production of zinc oxide.—**Guy de Bechi,** Paris.

"Precipitated hydrated oxide of zinc is heated to a bright red heat, and the calcined residue compressed, with or without the addition to it of carbon and a binding agent. The treatment is applied to the wet zinc process for the purpose of decomposing the oxychloride of zinc which remains with the precipitated hydrate, and so obtaining a purer oxide for reduction to metal."— J. S. C. I.

1193 17,057 of 1899. Zinc-lead ore treatment.—**Guy de Bechi,** Paris, France.

Process for smelting zinc-lead ores in a cupola furnace with common salt, whereby the zinc is driven off and the lead reduced.

1194 3,462 of 1900. Treating zinc ores and apparatus therefor.—**J. Armstrong,** London.

Blast furnace for reducing, volatilizing and condensing zinc out of contact with air. The method of condensing is especially claimed and can be adapted to any kind of furnace. Same as German Patent 132,139, Sept. 14, 1900.

—Described in Jour. Soc. Chem. Ind., vol. 20, p. 367. Apr. 30, 1901.

—Described also in Zeits. f. angewandte Chem., vol. 15, p. 766. July 29, 1902.

1195 3,668 of 1900. Treating complex ores (lead, zinc, sulphur, etc.), and apparatus therefor.—**J. W. Worsey,** St. Helens, and **J. H. Lancashire,** London. Patented also in Germany, no. 135,056.

—Described in Jour. Soc., Chem. Ind., vol. 20, p. 367. Apr. 30, 1901.

1196 10,915 of 1900. Process for extracting zinc, and apparatus therefor.—**Jules L. Babe** and **Alexis Tricart,** Paris.

"The zinc ore, mixed with coal and carbonate of soda, is heated in a special retort, whereby the zinc is extracted in one-third the time previously required."—J. S. C. I.

1197 15,166 of 1900. Treatment of slags and by-products containing zinc.—**H. F. Kirkpatrick-Pickard,** London.

Process of finely grinding, roasting, briquetting with carbonaceous material, and distilling.

1198 22,570 of 1900. Recovery of zinc from sulphide ores.—**H. F. Kirkpatrick-Pickard,** London.

"The process is for the treatment of unroasted sulphide ores by mixing them with a reducing agent, such as lime, iron or iron oxide, and a carbonaceous material suitable for coking, forming briquettes, and distilling the same in such a manner as to first form a coke and then reduce and volatilize the zinc, the resulting sulphide of calcium or iron and any non-volatile metals remaining in minute particles in the coke."—J. S. C. I.

1199 493 of 1901. Treatment of zinc ores.—**H. M. Taquet,** Argenteuil, France.

"The process consists of the production, in one operation, of metallic zinc and alkaline earth sulphides by distilling in zinc furnaces and in the presence of carbon, the compounds of zinc composed of oxide of zinc and the sulphate of an alkaline earth. The latter are produced by precipitating the mixed solution of chloride and sulphate of zinc with lime, baryta or strontia."—J. S. C. I.

1200 2,782 of 1901. Treatment of ores containing zinc.—**J. G. Butterfield,** Balham, Surrey. Feb. 8, 1901.

"The ores are roasted without fritting, and the product ground with caking coal to which limestone is added as a flux. The ore mixture is placed on a tray within a horizontal cylindrical iron retort, projecting beyond the furnace. An air-pump is provided for obtaining a vacuum within the retort to assist the distillation of the zinc."—J. S. C. I.

1201 8,175 of 1901. Method of and means for casting and simultaneously refining raw zinc and other metals excepting iron.—**E. Herter,** Beuthen, Silesia. Patented also in Germany, no. 132,141.

—Described in Jour. Soc. Chem. Ind., vol. 20, p. 724. July, 1901.

—German patent described in Zeits. f. angewandte Chem., vol. 15, p. 687. July 8, 1902.

1202 15,831 of 1901. Zinc or other distillation furnaces.—**Erminio Ferraris,** Monteponi, Sardinia, Italy.

Arranges the retorts so as to economize fuel and facilitate equalization of heating.

—Described in Jour. Soc. Chem. Ind., vol. 20, pp. 997-998. Oct. 31, 1901.

1203 17,415 of 1901. Reduction of zinc ores.—**L. Braunfels,** Frankfort-am-Main.

The ores are briquetted and "heated in an iron reduction vessel having a condenser and suitable connections, to a sufficiently high temperature to distil the zinc, a vacuum being induced; and finally a current of carbon monoxide or other inert gas is passed through to lead the zinc vapors to the condenser."—J. S. C. I.

1204 14,982 of 1902. Treatment of zinc ores and other zinc material.—**J. R. Down,** Swansea, England.

The ores are briquetted with coal by the use of from ½ to 2 per cent by weight of sago flour, the proportion of coal being about 30 per cent.

1205 16,723 of 1902. Saving zinc fumes.—**R. W. Western,** London.

Catching zinc fumes by agitation in a solution of sulphate of ammonia and precipitating as zinc hydroxide by addition of aqueous ammonia.

1206 6,185 of 1905. Fume recovery.—**G. A. Mower,** London.

"Fixing a hood around furnaces, such as zinc distilling furnaces, and drawing such fumes away by a fan to a settling chamber."—E. & M. J.

1207 14,573 of 1905. Reduction of zinc sulphides.—**Soc. Anon. Metallurgique Procedes de Laval,** Frankfort.

Reducing zinc from roasted sulphides by injecting the latter, together with carbon finely pulverized, into a whirling atmosphere of carbonic oxide gas.

1208 20,380 of 1905. Smelting zinc-lead sulphides.—**F. Mackay & A. J. Beckwith,** Melbourne, Australia.

"A process for smelting zinc-lead and other sulphides by injecting the ore in a state of very fine powder, together with a current of air, into a hot chamber; and methods of treating the oxides and sulphates so formed."—E. & M. J.

1209 98 of 1906. Retort discharging apparatus.—**An. de Biache St. Vaaste,** Paris, France.

"Apparatus for discharging zinc retorts by means of a blast of compressed air or steam."—E. & M. J.

—Described in Eng. & Min. Jour., vol. 82, p. 636. Oct. 6, 1906.

1210 19,130 of 1906. Smelting process.—**R. W. E. MacIvor** and **M. Fradd,** London.

"In treating complex sulphides, throwing the roasted ores into calcium chloride and then passing sulphurous acid into the mixture."—E. & M. J.

1211 24,905 of 1906. Extraction of metals from zinc-lead sulphide ores.—**J. C. Fernau,** Nelson, B. C. Nov. 6, 1906.

"Molten iron is caused to circulate between an air-tight working chamber and a superheating chamber, and zinc-lead sulphide ores are introduced into the working chamber. The zinc is volatilized, the vapors passing through incandescent carbon to a condenser. The lead settles to the bottom of the molten iron in the working chamber and is tapped off, and iron sulphide is also withdrawn, from time to time, from the surface of the molten metal."—J. S. C. I.

1212 4,563 of 1909. Means for treating fumes from zinc retorts. —**H. E. Howard** and **G. Hadley,** Halesowen, England. Feb. 24, 1909.

A carbon filter for attachment to the open end of the zinc condenser.

1213 9,955 of 1909. Filter for zinc distillation.—**C. S. Brand.**

Retort filter for catching volatilized lead.

—Described in Min. Mag., vol. 2, p. 457. June, 1910.

1214 22,704 of 1909. Nozzle for catching zinc fume that escapes from the condenser.—**Wm. Rees,** Swansea, England.

—Described in Min. Mag., vol. 4, p. 58. Jan., 1911.

1215 3,951 of 1912. Process for the treatment of sulphide ores, tailings and other residues containing lead and zinc.— **A. Richards,** London.

"A mixture of the material with a reducing agent and a small quantity of sodium chloride or a suitable bromine-containing substance is subjected to a temperature sufficient to expel the zinc or lead, or both, as haloid compounds."—J. S. C. I.

1216 732 of 1913. Improvements in, or relating to, apparatus for the continuous removal of the residues from the reduction of zinc ores in vertical retorts.—**R. Roitzheim,** Cologne, and **W. Remy,** Aix-la-Chapelle.

1217 1,701 of 1913. An improved process and apparatus for the condensation of vapors of volatile metals, especially zinc vapor.—**F. G. W. Timm,** Hamburg, Germany.

Patented also in France, No. 454,49[illegible].

1218 17,648 of 1913. Method of manufacture of zinc from poor zinc-ore and tailings.—**F. C. Beauchamp.**
—Described in Min. Jour., vol. 100, p. 269. Mar. 15, 1913.

1219 1,930 of 1915. Retort furnaces for the recovery of volatile metals such as zinc.—**E. Gellbach,** Hohenlohehuette.

The regenerative heating system is employed, but the direction of the flame is maintained constant in the combustion chamber of the retort furnace in order to insure uniform heating.

1220 8,265 of 1915. Zinc smelting furnace.—**E. Ruck,** Swansea.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 1066. October 31, 1916.

1221 9,009 of 1915. Recovery of zinc.—**F. W. Highfield,** Whitchurch-on-Thames, Oxford.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 850, Aug., 1916.

1222 115,409. Extraction of zinc.—**E. H. Shortman, jr.,** and **New Delaville Spelter Co., Ltd.,** Birmingham. Appl. No. 10,385 of 1917.

"A zinc retort is connected with a condenser of large capacity by a passage provided with a lead-intercepting and filtering device."—J. S. C. I.

1223 122,566. Increasing the production of zinc dust from spelter retorts.—**C. W. and C. Crocker,** Irvine, England. Appl. No. 7,025 of 1918.

"A set of baffles, not in alignment, mounted on a frame is inserted in the prolong used in connection with a zinc distillation retort, to facilitate the deposition of zinc dust."—J. S. C. I.

1223a 122,688. Metallurgy of zinc.—**J. Armstrong,** London. Appl. No. 1,603 of 1918.

"Oxidized zinc ore is comminuted with bituminous coal, the mixture subjected to a low temperature coking process out of contact with air, and the resulting mass crushed and charged continuously into vertical tubular retorts formed in three sections, the middle one of which is heated and constitutes the reduction retort. This section is made of pure silica and corundum."—J. S. C. I.

France

1224 339,752. Recovery of zinc and lead from ores.—**Miller.** June, 1904.

Broken-Hill refractory ores are mixed with fine silicide and with tar, and eventually with lime, if silver is present. The mixture is ground, placed in a retort and heated slowly. Sb and Bi distil first, then Zn. Pb and Ag remain as metal in the retort.

1225 348,733. Treatment of zinc ores.—**E. Demenge.** Dec. 9, 1904.

"The ores are smelted in a water-jacketed cupola furnace, using a strong blast. The volatilized lead and the precious metals are recovered in the metallic state. Zinc is volatilized and drawn off by a fan through a series of cooling and condensing chambers where it is deposited as oxide."—J. S. C. I.

1226 363,036. Manufacture of zinc.—**R. Fritsch** and **E. Nonnast.** Feb. 6, 1906.

"Before being distilled, the mixture of zinciferous mineral and carbonaceous material is first molded into blocks corresponding with the cross-section of the retort. This facilitates charging the retorts, and enables 35% to 40% more material to be distilled in one operation."—J. S. C. I.

1227 366,380. Retort, muffle, etc., for the reduction of zinc ores and other purposes.—**D. Delville et Cie. des Metaux et Prod. Chim. d'Overpelt.** May 18, 1906.

"The retort is provided on the outside with a number of horizontal channels for the better utilization and transmission of the heat supplied."—J. S. C. I.

1228 446,576. Treatment of complex ores of zinc, lead, silver, gold and copper.—**A. J.** and **R. J. Merle.** Oct. 4, 1911.

"The crushed ore is melted with suitable fluxes in a furnace provided with powerful aspirators. The lead and zinc are volatilized and thus separated from the other metals. By injecting a solution of glucose into the aspirators, the lead and zinc salts contained in the gases from the furnace are retained. The glucose solution is run into settling tanks where the insoluble lead salts separate as mud. The decanted solution is used again and again, until sufficiently rich in zinc salts, which are then precipitated by the addition of lime." —J. S. C. I.

1229 477,653. Process for the separation of lead and zinc.—**J. Babe.** June 24, 1914.

Roasted ores containing lead and zinc are intimately mixed with finely powdered sulphur and carbon, and heated to 800° to 900° C., whereby lead sulphide is formed and volatilized, leaving the zinc as oxide. Ores containing the metals as sulphides are heated directly with carbon, without roasting or addition of sulphur.

—Described in Jour. Soc. Chem. Ind., vol. 35, pp. 606-7. May 31, 1916.

1230 478,942. Condenser for vapors of lead and zinc.—**Soc. Anon. Metallurgique "Procedes dé Laval".** June 7, 1915.

—Described in Jour. Soc.' Chem. Ind., vol. 35, pp. 1118-19. Nov. 15, 1916.

1231 479,039. Process for the treatment of low-grade, complex ores.—**H. E. L. Fievet.** June 15, 1915.

Low-grade ores containing, for example, lead, zinc, arsenic, antimony, and precious metals, are mixed with oxide and sulphide ores of iron and a little copper, and the mixture smelted with iron slag in a water-jacketed furnace, to produce a matte containing all the metals. The matte is tapped into a converter and "blown" in the presence of powdered coke to eliminate the more volatile metals, which are recovered as oxides or sulphates, leaving a matte rich in copper and containing the precious metals.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 1119. Nov. 15, 1916.

Germany

1232 107,247. Muffle furnace for distilling zinc, cadmium and the like.—**Carl Francisci,** Silesia. April, 1899.
—Described in Zeits. f. angewandte Chem., vol. 13, pp. 20-21. Jan. 2, 1900.

1233 117,614. Zinc smelting furnace with separate smelting and reduction chambers.—**Amedie Sebillot,** Paris. Jan., 1900.
—Described in Zeits. f. angewandte Chem., vol. 14, pp. 296-97. Mar. 19, 1901.

1234 137,004. Zinc distillation with simultaneous recovery of earth-alkali-sulphides.—**Henri M. Taquet,** Argenteuil, France. Mar. 21, 1901.
—Described in Zeits. f. angewandte Chem., vol. 15, p. 1227. Nov. 25, 1902.

1235 139,293. Smelting muffle residues of zinc furnaces.—**Adolf Savelsberg,** Ramsbeck, Germany. Apr. 3, 1902.

1236 140,554. Zinc smelting in a shaft furnace.—**Paul Schmieder,** Lipine, Silesia, Germany. Mar. 26, 1902.
—Described in Zeits. f. angewandte Chem., vol. 16, pp. 683-84. July 14, 1903.

1237 154,695. Process for the recovery from their sulphides of zinc, lead, and other metals having a slighter affinity for sulphur than has copper.—**Antoine H. Imbert,** Nov. 15, 1903.

1238 156,342. Muffle for the distillation of zinc and cadmium.—**O. Unger.** July 31, 1903.

"The furnace consists of two or more thin-walled muffles fitting one within the other, with, if necessary, spaces between. Strains during heating and cooling, and the formation of cracks are thus avoided."—J. S. C. I.

1239 165,243. Refining zinc and other metals by continuous distillation.—**Jacob Callman** and **Rudolph Bormann,** Berlin. Mar. 21, 1905.
—Described in Zeits. f. angewandte Chem., vol. 19, p. 1619. Sept. 21, 1906.

1240 169,612. Process for the recovery of zinc and other volatile metals in the shaft furnace.—**Hermann Mehner,** Berlin. Jan. 1, 1904.
—Described in Zeits. f. angewandte Chem., vol. 20, p. 159. Jan. 25, 1907.

1241 173,103. Process for removing zinc from burnt pyrites, and for utilizing the pyrites for the production of iron by smelting.—**Elektrische Zinkwerke G. m. b. H.** Mar. 20, 1904.

The pyrites is treated in a reverberatory furnace with two hearths, being heated in presence of a reducing agent to the volatilizing temperature of zinc, and finally to the fusing point.

1242 180,981. Process for working up zinciferous materials, simultaneously using the zinc and carbon content of the smelter residues.—**Gustav Stolzenwald,** Ploest, Roumania. Nov. 8, 1905.

1243 195,793. Recovery of zinc, lead, and the like, from their sulphide ores by precipitation with iron, copper, and the like.—**Antoine H. Imbert.** May 11, 1906.
—Described in Zeits. f. angewandte Chem., vol. 21, p. 1243. June 5, 1908.

1244 207,019. Process for the recovery of zinc from zinciferous lead and other low-grade zinc alloys.—**D. Coda.** June 21, 1907.

"An alloy of copper, or of copper and aluminium with lead is added to the fused alloy containing zinc, in order to concentrate the zinc dross which is practically free from silver and can be distilled."
—J. S. C. I.

1245 212,890. Apparatus for charging retorts of zinc ard other metallurgical furnaces.—**Emile Dor-Delattre,** Budel, Holland. July 13, 1907.
—Described, with diagr., in Zeits. f. angewandte Chem., vol. 22, p. 2297. Nov. 19, 1909.

1246 212,897. Process for recovery of zinc from ores and smelter products, especially from zinc sulphide ores containing copper, by adding chloride of an alkali or earth alkali, and smelting.—**Emil Vuigner,** Paris. Oct. 28, 1906.

1247 218,408. Recovery of zinc from its oxide or sulphide ores, or from a mixture of both, precipitating by means of metal, and using an iron-bearing solvent (Fe_2O_3) for the zinc ore.—**Imbert Process Co.,** New York.
—Described in Zeits. f. angewandte Chem., vol. 23, pp. 806-7. Apr. 29, 1910.

1248 231,694. Process for the recovery of zinc by reduction in the muffle.—**Aktien-Gesellschaft f. Bergbau, Blei- und Zinkfabrikation,** Aix-la-Chapelle. Jan. 28, 1908.
—Described in Zeits. f. angewandte Chem., vol. 24, p. 611. Mar. 31, 1911.

1249 232,097. Process for the treatment of mixed lead-zinc sulphides, with simultaneous recovery of the metallic lead and zinc oxide.—**Wilhelm Witter,** Hamburg. Sept. 17, 1908.
See also 240,365, below.
—Described in Zeits. f. angewandte Chem., vol. 24, pp. 715-16. Apr. 14, 1911.

1250 238,292. Working up low-grade zinc ores, especially calamine.—**Gilbert Dantin,** Lyons, France. Oct. 21, 1909.
—Described in Zeits. f. angewandte Chem., vol. 24, p. 1980. Oct. 13, 1909.

1251 240,365. Treatment of mixed lead-zinc sulphides, with simultaneous recovery of metallic lead and zinc oxide, the oxide ores being reduced with iron.—**Wilhelm Witter,** Hamburg, Germany. Oct. 19, 1909.
Modification of 232,097, above.
—Described in Zeits. f. angewandte Chem., vol. 24, p. 2275. Nov. 24, 1911.

1252 244,893. Process for the recovery of metallic zinc or zinc dust from sulphide materials such as blende, roasted zinc sulphide or zinc ore intimately mixed with gangue, by heating with hydrogen or with hydrogenous gases and compounds.—**Kurt Friederich,** Breslau, Germany. July 24, 1910.
—Described in Zeits. f. angewandte Chem., vol. 25, pp. 981-82. May 10, 1912.

1253 245,503. Process for the distillation of zinc, using a haloid salt.—**Central Zinc Co., Ltd.,** Seaton Carew, England. Dec. 21, 1910.
—Described in Zeits. f. angewandte Chem., vol. 25, p. 982. May 10, 1912.

1254 245,681. Process for the recovery of zinc by distillation.—**H. Specketer,** Griesheim, Germany. July 27, 1909.
—Described in Zeits. f. angewandte Chem., vol. 25, p. 982. May 10, 1912.

1255 248,750. Process for the recovery of metallic zinc from zinc dust.—**Charles Thierry.** April 2, 1911.

—Described in Zeits. f. angewante Chem., vol. 25, p. 1871. Sept. 6, 1912.

1256 253,640. Process and apparatus for recovery of zinc in a shaft furnace with blast feed below.—**Antoine B. Pescatore,** London, England. June 8, 1911.
—Described in Zeits. f. angewandte Chem., vol. 26, pt. II, p. 56. Jan. 28, 1913.

1257 255,918. Distillation furnace with vertical muffles or other suitable reduction-chambers, for the recovery of zinc or other volatile metals.—**Rheinisch-Nassauische Bergwerks-und Huetten-Akt.-Gesell.,** Stolberg, Germany. Feb. 11, 1912.
—Described in Zeits. f. angewandte Chem., vol. 26, pt. II, p. 128. Feb. 25, 1913.

1258 256,083. Process for obtaining metals such as zinc, lead, etc., from their compounds with oxygen or sulphur.—**R. von Zelewski.** May 19, 1912.

"Heating with carbides, a chloride compound of an alkali or alkaline-earth metal being added to facilitate the reaction."—J S. C. I.

1259 260,749. Process for the distillation of zinc and other volatile metals from ores or the like by introducing an air current, in a discontinuously working furnace, through an ignited mixture of the ore or smelting product with fuel, and allowing the residue to sinter together.—**Wilhelm Troeller,** Frankfurt-am-Main, Germany. Dec. 11, 1909.
—Described in Zeits. f. angewandte Chem., vol. 26, pt. II, pp. 440-41. July 22, 1913.

1260 265,061. Process for the condensation of zinc vapors.—**F. C. W. Timm,** Hamburg. Feb. 21, 1912.
—Abstract. Zeits. f. angewandte Chem., vol. 26, pt. II, p. 687. Nov. 18, 1913.

1261 265,805. Apparatus for the condensation of zinc vapors which are obtained by the reduction of pure zinc oxide in suitable retorts.—**Pierre Ferrere,** Paris. Mar. 7, 1912.
—Described, with diagr., in Zeits. f. angewandte Chem., vol. 26, pt. II, pp. 687-88. Nov. 18, 1913.

1262 268,028. Removable condenser for zinc distillation furnace.—**Carl Reichmann,** Kattowitz, Silesia. Dec. 4, 1912.

Consists of an iron jacket lined with asbestos.

1263 271,827. Process and apparatus for liquefaction of zinc vapor in the zinc furnace.—**Charles V. Thierry,** Paris. July 20, 1912.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 258. Apr. 17, 1914.

1264 276,292. Distillation furnace for zinc and the like, rotating upon a horizontal axis.—**Hermann Hantelmann,** Merseburg, Germany. Mar. 28, 1913.
—Described, with diagr., in Zeits. f. angewandte Chem. vol. 27, pt. II, p. 522. Sept. 4, 1914.

1265 286,535. Method and apparatus for removing hot residues from muffles.—**E. Gellbach** and **M. Matt,** Hohenlohehuette, Silesia.

The residues are removed by jets of air and water, assisted by scrapers attached to the outer tube of the device through which the water and air are introduced.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 185. Feb. 15, 1916.

1266 287,122. Manufacture of zinc muffles.—**Celludin Co.,** Berlin.

The muffle is made from a mixture containing an amount of zirconia equal to from 1% to 10% of the whole. A suitable mixture is composed of 33.3% clay, 1 to 10% zirconia, and "grog" (burnt fire-clay).

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 185. Feb. 15, 1916.

1267 289,720. Process for obtaining zinc.—**E. Fleischer,** Dresden, and **Bunzlauer Werke Lengersdorf und Co.,** Bunzlau, Germany. June 7, 1912.

A mixture of ore and reducing agent (carbon) is treated in externally heated retorts with reducing gases (e. g., a mixture of carbon monoxide and nitrogen), the temperature of which is at least 1000°C., and the gases from the retorts are led through a condenser maintained at a temperature between the melting point and vaporization point of zinc, e. g., at 500° to 600° C.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 427. Apr. 15, 1916.

1268 291,043. Process for improving the durability of muffles for distillation of zinc.—**A. Zavelberg,** Hohenlohehuette, Silesia. April 3, 1914.

A pair of muffles, one fitting loosely inside the other, with the intermediate space packed with finely ground silica or washed sea-sand.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 641. June 15, 1916.

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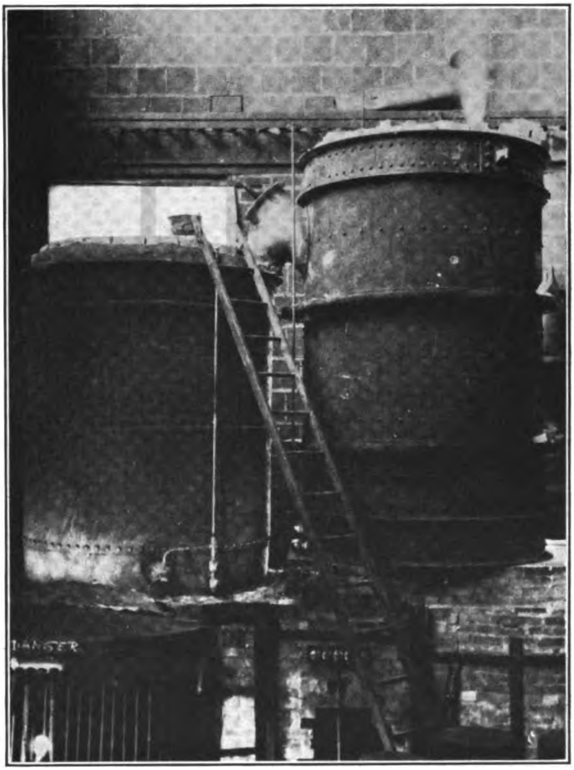
1270 294,287. Process for separating zinc from alloys containing it.—**G. Heinecker,** Breslau. Feb. 5, 1916.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 1161. Nov. 30, 1916.

1270a 306,725. Production of zinc of high purity from impure metal and alloys in vacuo.—**E. Herter,** Berlin. July 6, 1915.

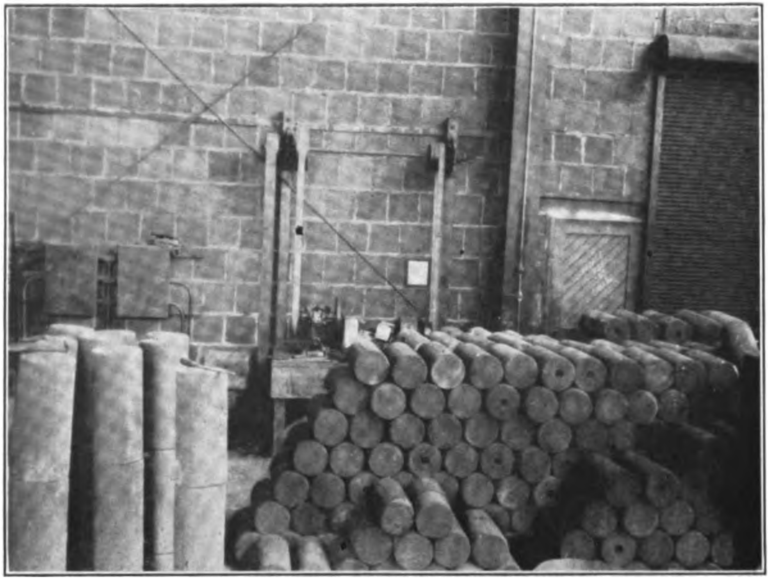
"In the vacuum distillation of zinc the condensed liquid metal is continuously drawn off, without imparing the vacuum, by maintaining a column of the liquid metal of sufficient height to balance the atmospheric pressure."—J. S. C. I.

1270b 308,156. Furnace for refining zinc.—**W. Nestmann,** Coeln-kalk, Germany. Sept. 27, 1917.

"The floor of the furnace slopes toward a lateral taphole leading into a well where the lead separates out."—J. S. C. I.



FULTON'S ELECTRIC FURNACE
Retort and condenser with top connection. Condenser to the right. Note the carbon monoxide flame.



FULTON'S ELECTRIC FURNACE
Briquettes, 9 1/4 inches diameter, 22 inches long

ELECTRO-THERMIC SMELTING

Bibliography

1271 Bibliography on the development of the electric furnace.—**Adolph Minet.** Faraday Soc., Trans., vol. 2, pp. 25-28. May, 1906.

The Electric furnace, with special reference to zinc metallurgy

1272 A brief description of working models of electric furnaces, by the Philadalphia Electric Co. Amer. Electrochem. Soc., Trans., vol. 11, pp. 411-14. 1907.

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1274 Combined fuel and electrically heated refining furnace, diagr. Met. & Chem. Eng., vol. 16, pp. 531-32. May 1, 1917.

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—Abstract. Met. & Chem. Eng., vol. 11, pp. 652-54. Nov., 1913.

1276 Determinations of the constants of materials for furnace electrodes.—**Carl Hering.** illus., diagr. Amer. Electrochem. Soc., Trans., vol. 17, pp. 151-70. 1910.

—Abstract: Laws of furnace electrodes. Met. & Chem. Eng., vol. 8, pp. 329-30. June, 1910.

1277 The electric furnace; its origin, transformation and applications.—**Adolphe Minet.** illus. Faraday Soc., Trans., vol. 1, pp. 77-102, and vol. 2, pp. 1-31. Jan., 1905, and May, 1906.

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Discusses (a) Furnaces for reduction of metals from their ores; and (b) Furnaces for heating, refining and distilling metals.

—Same. Min. Jour., vol. 113, pp. 233-34, 284-85, 291-92, 330-31. Apr. 8, 22, 29, May 13, 1916.

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1280 Electric furnaces; their design, characteristics and commercial application.—**Woolsey McA. Johnson** and **George N. Sieger.** Met. & Chem. Eng., vol. 11, pp. 504-7, 563-67, 643-48, 683-86. Sept. - Dec., 1913.

Series of articles "designed for three classes of readers, i. e., Engineering students who wish to learn the technology of electric furnaces, engineers who desire in convenient form a "desk book" covering the latest intensive application of electrical energy, and business men who might need to learn quickly the general principles of electrical furnaces."

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Electric smelting of zinc

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"Ascribes lack of success to the amount of blue powder produced, and attributes its formation to the oxidation of the reduced zinc by carbonic acid."—Clerc. Points out a number of conditions that must be filled to render the electric furnace efficient. See also item 1390.

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1316 Electric furnaces for treatment of zinc ores.—**J. H. Lawrie.** diagr. Min. Wld., vol. 35, pp. 283-85. Aug. 12, 1911.

Louvrier electric furnace.

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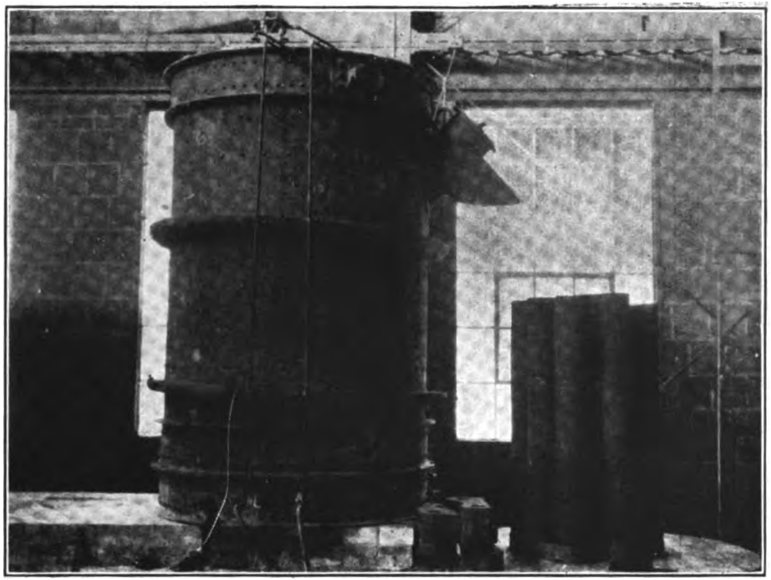
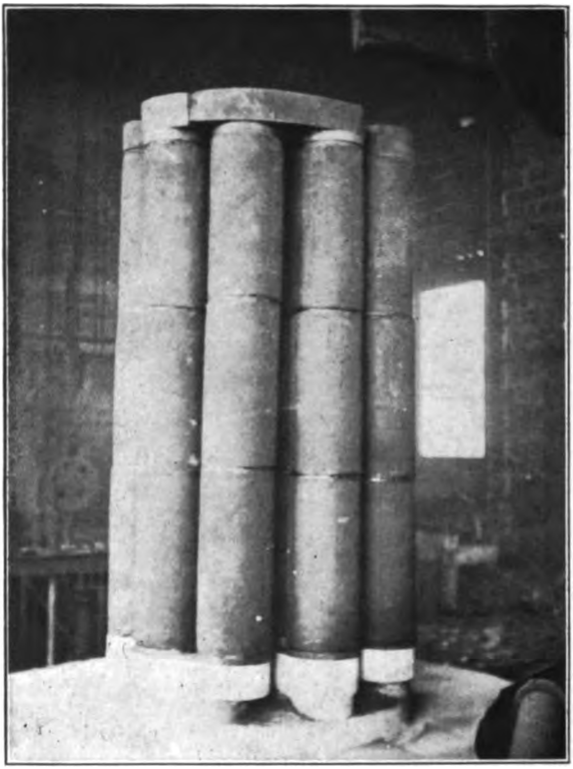


FULTON'S ELECTRIC FURNACE
Charge on right base; top graphite connectors not yet placed; condenser with top connection on left.



FULTON'S ELECTRIC FURNACE
A charge of 12 columns, 36 briquettes, weight 3160 lbs., containing 1700 lbs. of ore, set up on base ready for distillation.

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1330 Electric zinc furnace. diagr. Electrochem. & Met. Ind., vol. 5, p. 103. Mar., 1907.

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Thierry's Patent 1,110,359. Resistance furnace for the reduction of zinc oxide obtained as a product of igneous concentration.

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Advantages and disadvantages of electric over ordinary retort smelting, briefly summarized and discussed.

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W. M. Johnson's Patent 964,268, and Hixon's Patents 957,058 and 957,337.

1339 Electric zinc smelting. Met. & Chem. Eng., vol. 12, p. 531. Aug., 1914.

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1340 Electric zinc smelting.—**Eugene Fleurville.** diagr. La Houille Blanche, vol. 7, p. 273. Dec., 1908.

Comparisons are given as to cost of plant, fuel, up-keep,etc., and losses sustained in smelting. The Cote-Pierron process is then described. In French.

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Experimental facts in W. McA. Johnson's attempts to produce a continuous electric zinc-smelting furnace.

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1346 Electrometallurgy of zinc.—**E. Ferraris.** Electrochem. & Met. Ind., vol. 4, p. 331. August, 1906.

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1347 The electrometallurgy of zinc.—**Gustave Gin.** diagr. Amer. Electrochem. Soc., Trans., vol. 12, pp. 117-39. 1907.

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1348 Electro-metallurgy of zinc and its relation to present practice.—**Woolsey McA. Johnson.** Amer. Electrochem. Soc., Trans., vol. 11, pp. 265-77. 1907.

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1349 The electrothermic reduction of zinc.—**C. E. Lesher,** Colorado School of Mines, Bull., vol. 4, no. 4, pp. 206-33. Jan., 1909.

1350 Electrothermic zinc smelting in Puebla, Mexico.—**Hiram W. Hixon.** Eng. & Min. Jour., vol. 101, pp. 1080-81. June 17, 1916.

"Description of the operation of the Teziutlan Copper Co.'s plant. The ores run 4% copper and 10% zinc. The zinc is obtained as dust for cyanidation work." Blowing of unreduced charge into the condenser with the vapor, and problem of forcing the charge in at the bottom of furnace were chief obstacles.

1351 Elektrische Zinkgewinnung; III-Elektrothermische Zinkgewinnung.—**J. Hess.** diagr. Zeits. f. Elektrochem., vol. 10, pp. 764-68. Sept. 23, 1904.

Reviews the principal electric zinc smelting methods up to 1904. Pts. I and II are on electrolytic methods.

—Abstract. diagr. Electrochem. Ind., vol. 2, pp. 457-58. Nov., 1904.

1352 Elektrischer Ofen fuer metallurgische Zwecke, z. B. fuer die Gewinnung von Zink und dergl., bei dem Elektroden vorhanden sind, die mit in der Waerme elektrisch leiten-

der Masse ueberstampft sind und zwischen denen allen Potentialdifferenz herrscht. diagr. Metall u. Erz, vol. 12, p. 511. Dec. 22, 1915.

Electric furnace for metallurgic use, especially for zinc recovery. German Patent 288,684, by Coswiger Braunkohlewerke.

1353 Elektrischer Ofen zur Gewinnung von Zink oder anderen fluechtigen Metallen mit einer Mehrzahl uebereinanderliegender Elektroden, die Mantelteile des Schachtes bilden. diagr. Metall u. Erz, vol. 12, pp. 473-74. Nov. 22, 1915.

Otto Schneemilch's German Patent 288,616, for an electric furnace for recovering zinc and other volatile metals, with several super-imposed electrodes forming the lining of the smelting-chamber.

1354 Elektrischer Ofen zur kontinuierlichen Gewinnung von Zink aus Erzen. Metallurgie, vol. 6, p. 231. Apr. 8, 1909.

Cote & Pierron's German Patent 206,148, for a continuous electric zinc furnace.

1355 Elektrischer Widerstandsofen fuer beliebige Badlaengen.—**Felix Thomas.** diagr. Metallurgie, vol. 9, pp. 158-60. Mar. 8, 1912.

Electric resistance furnace with variable length of bath; has been used successfully for reduction of briquetted zinc blende by means of iron and iron sulphide.

—Abtract. Jour. Inst. Metals, vol. 7, p. 286. 1912.

1356 Elektrisches Verschmelzen von Zinkblende. Metallurgie, vol. 7, p. 160. Mar. 8, 1910.

Cote-Pierron process.

1357 Die Elektrizitaet im Huettenwesen.—**Hans Koch.** illus. Oester. Zeits. f. Berg- u. Huettenw., vol. 54, pp. 417-24, 429-36, 442-47, 467-70, 482-86. 1906.

1358 Le four electrique Louis Louvrier pour la reduction des minerais. Metaux et Alliages, vol. 10, no. 3, pp. 10-11. March, 1917.

1359 The Fulton electric zinc-smelting process. Met. & Chem. Eng., vol. 16, pp. 158-59. Feb. 1, 1917.

U. S. Patent 1,213,180.

—Abstract. Sci. Abst. B., vol. 20, pp. 134-45. Apr., 1917.

1360 Fulton's electric zinc furnace. diagr. Met. & Chem. Eng., vol. 18, pp. 539-40. May 15, 1918.

1361 La fundicion electrica del zinc. Mex. Min. Jour., vol. 16, p. 222. April, 1913.

1362 Gekuehlte Bodenelektrode fuer elektrische Schmelzoefen. diagr. Metall u. Erz, vol. 12, p. 105. Mar. 8, 1915.

German Patent 282,162, by F. Krupp, for cooled electrodes for smelting furnaces.

1363 Gewinnung von Zink durch Niederschlagsarbeit im elektrsichen Ofen. Metallurgie, vol. 6, p. 637. Oct. 8, 1909.

German Patent 210,030, by Cote and Pierron, for zinc extraction by precipitation in the electric furnace.

1364 The Gin electric furnace for zinc smelting. diagr. Eng. & Min. Jour., vol. 85, p. 1153. June 6, 1908.

Induction furnace for distillation. French Patent 382,872.

1365 The Imbert process.—**E. G. Spilsbury.** Min. & Sci. Press, vol. 92, p. 434. June 30, 1906.

1366 Johnson continuous electric zinc furnace. illus. Iron Age, vol. 89, pp. 1082-83. May 2, 1912.

Metallurgy, construction and operation.

1367 The Johnson electric zinc furnace.—**Joseph W. Richards.** illus., diagr. Amer. Electrochem. Soc., Trans., vol. 19, pp. 311-16. 1911.

—Abstract. illus. Met. & Chem. Eng., vol. 9, pp. 264-65. May, 1911.

—Abstract. diagr. Min. Mag., vol. 5, p. 310. Oct., 1911.

1368 The Johnson electric zinc process.—**Woolsey McA. Johnson.** Min. Wld., vol. 40, pp. 48-49. Jan. 10, 1914.

Discussion of comparative costs.

1369 Kontinuierliche Gewinnung von Zink in fluessigem Zustande in elektrischen Oefen mit beheiztem Kondensationsraum. diagr. Metallurgie, vol. 5, pp. 589-90. Oct. 8, 1908.

Cote & Pierron's German Patent 200,668, for the continuous extraction of zinc in fluid state in electric furnaces with heated condensation chambers.

1370 Manufacture of pure spelter.—**F. Juretzka.** Chem. Zeitg., vol. 40, pp. 885-86, 894-96. 1916.

Pure spelter (99.7—99.9% Zn) is obtained from refined metal (Pb 1, Fe .03%) by distillation at low temperatures. Electrically heated furnaces are much more advantages for this purpose than the ordinary gas-heated muffle furnaces. A central condensing system is more economical than muffles fitted with condensers, and allows of a reduced pressure.—J. S. C. I. In German.

1370a Métallurgie électrothermique du zinc.—**J. Escard.** Génie Civil, vol. 73, pp. 124-27, 141-46, 168-71. Aug. 17, 24, 31, 1918.

1371 The metallurgy of zinc. Eng. & Min. Jour., vol. 92, pp. 385-86. Aug. 26, 1911.

1372 The metallurgy of zinc; the new electrolytic and electrothermic methods.—**R. Sylvany.** Metal Industry, vol. 7, pp. 330-32, 362-64, 404-5. 1915.

1373 Neuerungen in der Elektrometallurgie des Zinks und des Kadmiums.—**Franz Peters.** diagr. Glueckauf, vol. 45, pp. 1401-13. Sept. 25, 1909.

Metal losses may be reduced; cheap power necessary; reduction of blende with iron requires high temperature; use of carbon. Describes several furnaces, especially the Cote-Pierron.

—Abstract: Recent advances in the electrometallurgy of zinc. diagr. Eng. & Min. Jour., vol. 89, pp. 1017-19. May 14, 1910.

—Abstract. Electrochem. & Met. Ind., vol. 6, p. 196. May, 1908.

1374 A new electric resistance furnace.—**Francis A. J. Fitzgerald.** illus., diagr. Amer. Electrochem. Soc., Trans., vol. 19, pp. 273-84. 1911.

Detailed description of Imbert process. Much the same paper as item 1312. See also item 1378.

—Same. illus., diagr. Met. & Chem. Eng., vol. 9, pp. 259-62. May, 1911.

1375 A new electric zinc smelting process. diagr. Met. & Chem. Eng., vol. 16, pp. 158-59. Feb. 1, 1917.

C. H. Fulton's Patent 1,213,180. The charge is the resistor. It is in the form of briquettes which preserve their form and volume during distillation.

—Same: Fulton's electric zinc furnace. diagr. Min. Mag., vol. 16, p. 220. April, 1917.

1376 A new resistor furnace.—**Francis A. J. Fitzgerald.** illus. Met. & Chem. Eng., vol. 8, p. 317. June, 1910.

"Specially designed for zinc smelting."

—Abstract. Jour. Inst. Metals, vol. 4, p. 294. 1910.

1377 A new type of electric furnace for the reduction of ores.—**Francis Louvrier.** diagr. Met. & Chem. Eng., vol. 11, pp. 710-13. Dec., 1913.

About half the paper discusses zinc ore reduction. In the author's furnace "the proportion of blue powder is not to exceed 3 per cent of the metal."

—Abstract. Jour. Inst. Metals, vol. 11, pp. 335-36. 1914.

1378 Note on an unsuccessful furnace experiment.—**Francis A. J. Fitzgerald.** Amer. Electrochem. Soc., Trans., vol. 20, pp. 281-86. 1911.

Owing to excessive heat losses, disappointing results were obtained from the furnace described above (item 1312 and 1374).

1379 Notes on electric zinc smelting.—**Woolsey McA. Johnson.** illus. Met. & Chem. Eng., vol. 10, pp. 537-38. Sept., 1912.

1380 Nuevo beneficio electrico de los minerales de zinc.—**Francis Louvrier.** Mex. Min. Jour., vol. 8, no. 4, pp. 35-36. April, 1909.

Author's electric smelting furnace.

1381 Possible applications of the electric furnace to Western metallurgy.—**Dorsey A. Lyon** and **Robert M. Keeney.** Amer. Electrochem. Soc., Trans., vol. 24, pp. 119-66. 1913.

Electric zinc smelting; smelting at Trollhatten, Sweden; experiments at McGill University; experiments of Johnson; electric smelting of zinc sulphide ores with iron as a desulphurizing agent.

—Abstract. Met. & Chem. Eng., vol. 11, pp. 577-81. Oct., 1913.

1382 Preventing blue powder in the electric reduction of zinc ores.—**Woolsey McA. Johnson.** Met. & Chem. Eng., vol. 13, p. 763. Oct. 15, 1915.

Author's Patent 1,150,271. "The ores are first calcined, at a roasting temperature of 950° C., with conditions such that sulphates other that those of barium, lead and calcium are decomposed........"

1383 Recent advances in the construction of electric furnaces for the production of pig iron, steel and zinc.—**Eugene Haanel.** Canada, Mines Branch, Bull. 3. 1910.

Discusses the Cote-Pierron furnace.

—Abstract: Electric smelting of zinc ore. diagr. Min. Mag., vol. 4, p. 65. Jan., 1911.

1384 Recent development of the Cote and Pierron electric zinc-smelting process. Met. & Chem. Eng., vol. 18, p. 17. Jan. 1, 1918.

"Interesting and hitherto unpublished details." Abstract of an article by G. Flusin in Bulletin Technique de la Suisse Romande, vol. 43, p. 233. Nov. 17, 1917.

—Abstract, in German. Metall u. Erz, vol. 15, pp. 147-48. May 8, 1918.

1385 Reducibility of metallic oxides as affected by heat treatment.—**Woolsey McA. Johnson.** diagr. Amer. Inst. Min. Eng., Trans., vol. 47, pp. 219-32. 1913.

Ease of reduction depends largely on the way the ores have been prepared.

—Same. Amer. Inst. Min. Eng., Bull. 79, pp. 1137-45. July, 1913.

—Abstract. Met. & Chem. Eng., vol. 11, p. 529. Sept. 1913.

1386 Reduction of zinc oxide. diagr. Met. & Chem Eng., vol. 11, p. 346. June, 1913.

Burgess' Patent 1,059,342. The zinc ore and the carbon reducing agent are kept separate, and the zinc oxide volatilized in an electric furnace.

1387 Reduction of zinc oxide in an electric furnace. diagr. Met. & Chem. Eng., vol. 13, p. 817. Nov. 1, 1915.

Highfield's Patent 1,153,786.

1388 Scandinavian electric zinc smelting. Eng. & Min. Jour., vol. 96, p. 1030. Nov. 29, 1913.

1389 The smelting of dross in the electric furnace.—**Raymond S. Wile.** illus. Min. Wld., vol. 42, pp. 501-4. Mar. 13, 1915.

"For the purpose of accelerating and completely extracting the zinc from the charge, which is in a molten condition, reaction agents in the form of strong bases are added exclusively, besides the normal reducing agents, which reaction agents drive off the zinc oxide as such from the complex silicates."

1390 Smelting zinc in an electric furnace.—**F. L. Clerc.** Met. & Chem. Eng., vol. 11, pp. 428-29. Aug., 1913.

Comment on Louvrier's article (item 1299) with additional data. Suggests that blue powder is not due to oxidation, that the position of the electrodes may not be responsible for rapid cooling of the zinc, etc. See also item 1342.

1391 Some present-day metallurgical problems.—**Dorsey A. Lyon.** Jour. Franklin Inst., vol. 177, pp. 187-222. Feb., 1914.

Five pages on electric zinc smelting.

—Abstract: Electrochemistry of zinc. Jour. Inst. Metals, vol. 11, pp. 320-21. 1914.

—Abstract. Mex. Min. Jour., vol. 19, pp. 257-60. Oct., 1914.

1392 Thermo-electric determinations of the reduction temperature of zinc oxide.—**Woolsey McA. Johnson.** diagr. Amer. Electrochem. Soc., Trans., vol. 5, pp. 211-20. 1904.

—Abstract: Reduction temperature of zinc oxide. diagr. Electrochem. & Met. Ind., vol. 2, pp. 185-87. May, 1904.

—Abstract. Eng. & Min. Jour., vol. 77, p. 1045. June 30, 1904.

—Abstract. Mineral Industry, vol. 12, pp. 363-64. 1903.

1393 Treating zinc bearing materials. diagr. Met. & Chem. Eng., vol. 13, p. 504-5. Aug., 1915.

W. McA. Johnson's Patent 1,146,075. The zinc of zincy slags is reduced with iron, the zinc being subsequently volatilized and condensed.

1394 Treatment of British Columbia zinc ores. Canad. Min. Jour., vol. 35, pp. 333-36. May 15, 1914.

Discussion of the investigations of the Mines Branch, especially in regard to electric smelting.

1395 Treatment of ferruginous zinc blende. Electrochem. & Met. Ind., vol. 5, p. 470. Nov., 1907.

W. McA. Johnson's Patent 868,345.

1396 Treatment of zinc-lead ores. diagr. Electrochem. & Met. Ind., vol. 4, pp. 503-4. Dec., 1906.

Snyder's Patent 834,644.

1397 Treatment of zinc ore in electric frnaces. Met. & Chem. Eng., vol. 14, p. 711. June 15, 1916.

Berglund's Patent 1,160,244. To prevent the formation of crusts of slag, etc., near the tap-hole, there are added at intervals certain easily fusible materials that will combine with and melt the crust.

1398 Ueber die elektrothermische Zinkgewinnung.—**H. Nathusius.** diagr. Metall u. Erz., vol. 15, pp. 87-93, 108-111. Mar. 22, Apr. 8, 1918.

Attempts hitherto have been failures because electric furnaces have not been constructed to solve the problem of the condensation of the zinc vapor. The author has designed a furnace whicn is described in detail.

—Abstract: Electrothermal smelting of zinc. Jour. Soc. Chem. Ind., vol. 36, p. 376A. July 15, 1918.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 31, p. 255. Aug. 9, 1918.

1399 Ueber die Verarbeitung von sulfidischen oder oxydischen Zinkerzen im elektrischen Ofen.—**Wm. Borchers.** Metallurgie, vol. 9, pp. 153-54. Mar. 8, 1912.

Treatment of sulphides or oxides of zinc in the electric furnace.

—Abstract. Zeits. f. angewandte Chem., vol. 25, p. 1705. Aug. 16, 1912.

1400 Ununterbrochenen Destillation von Zink. diagr. Metallurgie, vol. 1, p. 109. Mar. 22, 1904.

De Laval's German Patent 148,439. Electric furnace for continuous distillation of zinc. The zinc ore is mixed with coal dust, and distills at a high temperature.

1401 Verfahren, die bei Zinkgewinnung im elektrischen Ofen abziehenden Gase zu reduzieren und zu reinigen. diagr. Metall u. Erz, vol. 12, p. 253. June 22, 1915.

German Patent 284,866, by Trollhattan Elektrothermiska Aktiebolag, for reducing and refining vapors drawn off in electric zinc smelting.

1402 Verfahren und Ofen zur elektrothermischen Gewinnung fluechtiger metalle, insbesondere von Zink, durch Widerstandsheizung. Metall u. Erz, vol. 12, p. 104. Mar. 8, 1915.

German Patent 282,141, by Max Breslauer, for a furnace and process for electrothermic recovery of volatile metals, especially zinc, by heat resistance.

1403 Verfahren und Ofen zur Verfluessigung der Zinkdaempfe in Zinkoefen. diagr. Metall u. Erz, vol. 11, pp. 322-23. May 8, 1914.

Thierry's German Patent 271,827, for an electric furnace, and process for condensing the zinc vapors.

1404 Verfahren zur Darstellung von Zink und anderen aehnlich sich verhaltenden Metallen im elektrischen Ofen unter Benutzung der Beschickung als Heizwiderstand und Ofen zur Ausuebung des Verfahrens. diagr. Zeits. f. Elektrochem., vol. 19, pp. 280-82. Mar. 15, 1913.

Specketer's Patent 1,099,211, for producing zinc and other similar metals in a rotating electric furnace, using the charge as a resistance.

1405 Verfahren zur Herstellung von Zink unter Verwendung eines flussigen Schlackenbades. diagr. Zeits. f. Elektrochem., vol. 20, pp. 165-66. Mar. 1, 1914.

Tharaldsen's German Patent 261,188. To prevent formation of flue dust, the charge is introduced beneath or in a slag solution.

1406 Vorrichtung zur kontinuierlichen Gewinnung von Zink in fluessigen zustand in elektrischen Oefen mit beheiztem Kondensationsraum. Metallurgie, vol. 6, p. 225. Apr. 8, 1909.

Cote and Pierron's German Patent 206,311 for continuous extraction of zinc in fluid state in an electric furnace with heated condensation chambers.

1407 Zinc and lead from complex sulphide ores. Electrochem. & Met. Ind., vol. 4, p. 34. Jan., 1906.

Imbert's Patent 807,271. "Based on the property of metallic copper to act as a very energetic desulphurizer toward most of the ordinary metals." See also item 1045.

1408 Zinc extraction in the electric furnace. Min. Jour. vol. 94, p. 811. Aug. 5, 1911.

Snyder electric furnace for reducing plombiferous zinc ores at Slocan, B. C.

1409 Zinc in the electric furnace. Electrochem. & Met. Ind., vol. 3, pp. 209-10. June, 1905.

1410 Zinc metallurgy. Min. Mag., vol. 5, pp. 252-54. Oct., 1911.

Editorial on F. W. Harbord's work at Trollhattan.

1411 Zinc smelting at Trollhattan; summary of a report by **F. W. Harbord.** Eng. & Min. Jour., vol. 93, pp. 314-15. Feb. 10, 1912.

Electric zinc smelting, under De Laval patents. "Statement of results, including cost and extraction of metals, and reference to the condensation of zinc as powder as the weak point of the process."

1412 Zinc smelting in the electric furnace.—**Woolsey McA. Johnson.** diagr. Eng. & Min. Jour., vol. 96, pp. 965-67, 1041. Nov. 22, 29, 1913.

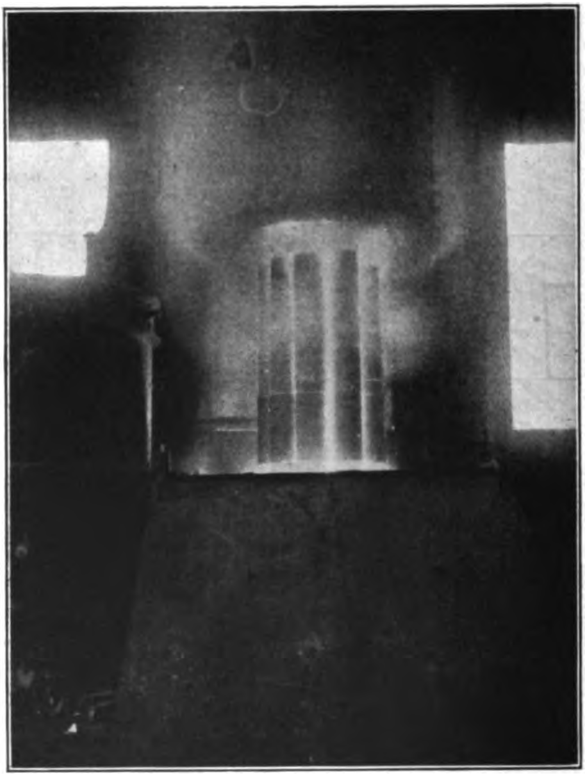
"Discussion of differences between electric and fire-smelting processes, and between electric-furnace slags and ordinary retort slags."

1413 Zink in Form von Zinkoxyd zu gewinnen. Metallurgie, vol. 2, p. 583. Dec. 22, 1905.

K. Kaiser's German Patent 162,762 for electric smelting of zinc ores without the addition of a reducing agent.

1414 Zinkfuehrende sulfidische Erze. Metallurgie, vol. 1, p. 204. May 22, 1904.

Danckwardt's Patent 746,797 and 746,798.



FULTON'S ELECTRIC FURNACE

Retort lifted, showing charge red hot. Twelve columns of 9-inch briquettes; 3160 lbs. Zinc vapor ready to be discharged. Condenser to left with bottom connection.

PATENTS ON ELECTRIC ZINC SMELTING

United States

1415 567,699. Electric smelting furnace.—**Joseph A. Vincent,** Philadelphia. Filed October 30, 1895. Issued September 15, 1896.

1416 640,283. Electric Furnace.—**Francis E. Hatch,** Norway, Mich. Filed Mar. 4, 1899. Issued Jan. 2, 1900.

A process for smelting ore, metal or the like, which consists in heating a series of refractory electric conductors by the application of an electric current by subjecting said conductors to the effect of the said current in sequence, and placing said conductors, after being so heated, successively in contact with the material to be smelted, associated with a suitable reducing agent whereby said material is smelted, at the same time other conductors of the said series are being heated by the current. 6 claims.

1417 643,254. Electric Furnace.—**Albert J. Peterson,** Notre Dame de Briancon, France. Filed Apr. 5, 1898. Issued Feb. 13, 1900.

In an electric oven, a chamber for the reception of the material to be reduced, an oven arranged below said chamber and having a flat hearth adapted to receive the reduced material, and two electrodes arranged in and having their upper surfaces level with the hearth of said oven, the upper flat surface of said electrodes adapted to be covered by and in contact with the reduced material and out of contact with the unreduced material, all arranged so that the reduced material on and between the electrodes is heated by the resistance it opposes to the passage of the curent between the electrodes the circuit of which is completed by said reduced material and the unreduced material is heated and reduced by contact solely with the heated reduced material.

1418 660,043. Electrical Furnace.—**Wilhelm Borchers,** Aix-la Chapelle, Germany. Filed Dec. 22, 1898. Issued Oct. 16, 1900.

In an electric furnace, the combination of a furnace structure, a feed-chute for the material operated upon, two electrodes adjustably arranged in the furnace to form an arc, one of said electrodes being disposed between the feed-chute and the other electrode and gradually tapered to a point, and means for feeding the material from the chute in a mass gradually decreasing in cross-sectional area over and past the tapered electrode to the arc, substantially as and for the purpose specified.

1419 705,651. Reduction of metals from their ores, etc., in electrically-heated furnaces.—**Ramon C. Contardo,** Sevres, France. Filed Dec. 1, 1897. Issued July 29, 1902.

The process of obtaining metal direct from the ore consisting in subjecting the lower end of a descending column of ore to a high temperature by a voltaic arc not in physical contact with the ore, and simultaneously causing a current of heated reducing-gas to flow upwardly through the column of ore. Patented also in England, No. 26,090 of 1902; In France, No. 334,103.

1420 716,008. Working zinc and substances containing silicic acid in electric furnaces.—**Alfred Dorsemagen,** Wesel, Germany. Filed Aug. 24, 1901. Issued Dec. 16, 1902.

A method of working a zinc-silicate ore consisting in preparing a charge of zinc silicate and carbon, then subjecting the charge to the action of an electric current sufficient to determine the reduction and volatilization of the zinc and the formation of carbide of silicon, and then suitably condensing the products of reduction and volatilization. Patented also in England, No. 16,122 of 1901; Germany, No. 182,534.

1421 736,611. Process of extracting zinc from its ores.—**Carl G. P. DeLaval,** Stockholm, Sweden. Filed November 15, 1901. Issued August 18, 1903.

The process of treating the ore of a volatilizable metal by radiant heat in an electric furnace which consists first in introducing said ore in comminuted state to form on the bottom of said furnace a pile or stack of gradually decreasing height sloping toward a source of electric heat, second, causing the non-volatile ingredient of said ore to melt and run down said surface so as to expose new layers of material constituting said stack to the action of said heat, and third, conducting the volatile metal vapors and generated gases by a separate outlet from said furnace and condensing said metal vapors.

1422 746,798. Process of recovering zinc from sulphide ores. —**Paul Danckwardt,** Deadwood, S. D. Filed August 15, 1903. Issued December 15, 1903.

The process of recovering and separating zinc and other valuable metals from ores or furnace product of a similar constitution, which consists in mixing the dry ore with a salt of an alkali metal, a carbide of any metal or a carbide-forming material, the carbide to be in excess over that required to bind all the oxygen of the charge in the form of carbon monoxide, mixing it further with fluxes for slagging of gangue and impurities of the ore, heating the mixture electrically under a heavy cover of carbon to prevent the formation of any carbon dioxide condensing the vapors of zinc and withdrawing the rest of the charge in a molten state, allowing the metals and matte to settle from the slag and sulphides of the alkali metal and calcium, dissolving the alkali sulphide in water, treating this solution with carbon dioxide, evaporating or crystallizing out the alkali carbonate and treating the escaping hydrogen sulphide for the recovery of the sulphur. 4 claims.

1423 750,753. Electric furnace.—**Ramon C. Contardo,** Sevres, France. Filed Aug. 24, 1900. Issued January 26, 1904.

1424 760,057. Process of electrically smelting materials.—**Alfred H. Cowles,** Cleveland, Ohio. Filed October 20, 1903. Issued May 17, 1904.

1425 768,054. Electric furnace.—**Carl P. G. De Laval,** Stockholm. Sweden. Filed May 8, 1903. Issued August 23, 1904.

1426 814,050. Electrical smelting process.—**Woolsey M. Johnson, Iola, Kans.** Filed May 24, 1904. Issued March 6, 1906.

The process of smelting zinc ores, which consists in interposing between a charge containing low-grade zinc ore and a furnace-wall, a charge containing high-grade zinc ore, thereby protecting said wall from the action of said low-grade ore. 13 claims.

1427 834,644. Process of treating ores.—**Frederick T. Snyder,** Oak Park, Ill. Filed June 21, 1905. Issued October 30, 1906.

The process of treating lead-zinc ores which consists in subjecting a body of such ores mixed with a reducing material, to a graduated heat sufficient to reduce the different metallic constituents thereof at different places in the ore body, collecting in a place of lower temperature the metal reduced at such temperature, progressively advancing the residue of the ore freed from such reduced metal to the place of increased temperature, and separately collecting the metal reduced at such higher temperature. 9 claims. See also item 1396.

1428 843,776. Electric furnace.—**Edward R. Taylor,** Pen Yan, N. Y. Flied May 1 51,902. Issued Feb. 12, 1907. 7 claims.

See also item 1330.

1429 843,777. Metallurgical process.—**Edward R. Taylor,** Penn Yan, N. Y. Filed May 27, 1902. Issued Feb. 12, 1907.

The metallurgical process which consists in feeding a suitable charge downwardly in proximity to the periphery of a furnace, and feeding portions of said charge inwardly through a surrounding body of the charge to a central reaction zone. 7 claims.

1430 859,132. Smelting process.—**Frederick T. Snyder,** Oak Park, Ills., assignor to Electric Metals Company, Chicago, Ills. Filed June 11, 1906. Issued July 2, 1907.

The process of treating lead-zinc sulphide ores which consists in subjecting the ore to an oxidizing roast, charging the furnace with roasted ore and carbon and fluxes adapted to form a slag at a temperature well above the boiling point of zinc, electrically developing heat in a limited zone in the furnace, sufficient to reduce the charge and keep the slag fluid, producing in the furnace slag, matte, metallic lead and a mixture of zinc and carbonic oxide allowing the carbonic oxide a restricted escape while condensing the zinc mixed therewith, progressively returning said condensed zinc to the zone of maximum heat and revaporizing said zinc, maintaining a flow of cooling fluid around the furnace wall, condensing the zinc vapor thereat in liquid form and drawing the liquid zinc from said walls and collecting the same. 27 claims.

—Described in Jour. Soc. Chem. Ind., vol. 26, p. 878-79. Aug. 15, 1907.

1431 859,133. Smelting furnace.—**Frederick T. Snyder,** Oak Park, Ills., assignor to Electric Metals Company, Chicago, Ills. Filed June 18, 1906. Issued July 2, 1907.

In an electric zinc-smelting furnace the combination with a base of a refractory material having a crucible therein, of a water-jacketed wall surmounting said base to form a furnace chamber, the top of said chamber being open, a bath of molten conducting material in said crucible, a carbon electrode extending down through the open top of the furnace and making electrical connection with said molten bath, said furnace having an outlet for zinc opening off the furnace chamber at a point above said molten bath, said outlet being sealed against the passage of gas therethrough. 25 claims.

1432 859,134. Smelting process.—**Frederick T. Snyder**, Oak Park, Ills., assignor to Electric Metals Company, Chicago, Ills. Filed June 25, 1906. Issued July 2, 1907.

The process of treating ores of metals which are volatile at reduction, which consists in separately smelting successive isolated charges of such ore with reducing material and fluxes, heating a portion of each charge first to a temperature sufficient to drive off most of the gaseous compounds of the reducing agent, while maintaining a free surface of the charge sufficiently cool to condense the metallic vapor within the body of the charge, then further heating said charge as a whole to a degree sufficient to drive off substantially all of said volatile metal, fusing the residues to form a slag and superheating the slag, while collecting the vaporized metal. Patented also in England, No. 13,254 of 1907.

1433 859,135. Metallurgical process.—**Frederick T. Snyder**, Oak Park, Ills., assignor to Electric Metals Company, Chicago, Ills. Filed June 30, 1906. Issued July 2, 1907.

The process of treating lead zinc sulphide ore which consists in partially roasting the ore, then mixing it with gaseous coal, limestone and iron, and smelting the mixture in a crucible closed against the external air, producing molten lead which collects at the bottom of the crucible, a layer of matte above the lead, and molten slag above the matte; said matte serving to protect the lead from the action of the slag, the zinc being reduced and volatilized and diluted with large quantities of other gases from the materials of the charge; and condensing the zinc vapor in the form of zinc dust. 18 claims.

1434 859,136. Electric furnace.—**Frederick T. Snyder**, Oak Park, Ills., assignor to Electric Metals Co., Chicago, Ills. Filed June 30, 1906. Issued July 2, 1907. 14 claims.

1435 859,137. Electric furnace.—**Frederick T. Snyder**, Oak Park, Ills., assignor to Electric Metals Co., Chicago, Ills. Filed July 25, 1906. Issued July 2, 1907. Patented also in England, No. 19,712 of 1906; in France, No. 369,756.

See also item 1331.

—Described in Jour. Soc. Chem. Ind. Vol. 26, p. 878-79, Aug. 15, 1907.

1436 868,345. Process of treating ferruginous blende.—**Woolsey M. Johnson**, Iola, Kans. Filed Jan. 11, 1904. Issued Oct. 15, 1907.

The method of producing zinc, which consists in passing an electric current through a charge containing a compound of zinc and metallic iron, thereby heating the charge and reducing the compound of zinc. See also item 1395.

1437 904,263. Process of obtaining metals from their ores.—**Karl Kaiser**, Berlin, Germany. Filed June 22, 1906. Issued November 17, 1908.

The process of obtaining separately zinc and iron from pyrite residues and products of smelting works which consists in heating the raw products in an electric furnace, until the material melts, then forcing atmospheric air through the mass, until the metals are oxidized, then forcing carbon monoxide through the mass, leading off the zinc vapors and condensing same and running off the molten iron into molds.

1438 920,473. Distillation furnace.—**Woolsey M. Johnson,** Hartford, Conn., assignor to The Continuous Zinc Furnace Company, Hartford, Conn. Filed May 8, 1906. Issued May 4, 1909.

An electric furnace comprising a furnace chamber having a vapor outlet, a permeable casing of refractory non-conductive material within said furnace chamber and spaced therefrom, electrodes disposed at opposite ends of said casing out of arcing relation, and means for feeding a charge to the interior of said casing. 5 claims.

—Described in Eng. & Min. Jour., vol. 88, p. 210. July 31, 1909.

1439 933,133. Process of treating zinc ores.—**Frederick T. Snyder,** Oak Park, Ills., assignor to Electric Metals Company, Chicago, Ills. Filed June 23, 1905. Issued Sept. 7, 1909.

The continuous process of treating slag forming ores containing zinc and lead, which consists in pre-heating the ore with carbon to drive off gases and to start the process of reducion, then continuing the reduction in an electric furnace in the absence of air, at a temperature sufficient to volatilize the zinc without volatilizing the lead, said ore being mixed with carbon and with iron, silica and lime in such proportions as to form a slag at said temperature, said mixture being fed upon a bath of said slag in the furnace, an electric current being passed through said slag to maintain said temperature, collecting the reduced and volatilized zinc, removing the other products of smelting and adding further charges from time to time, including quantities of carbon in excess of the amount required for reduction without interrupting the operation or admitting air. Patented also in France, No. 369,756. See also item 1323.

—Described in Min. Mag., vol. 1, p. 220. Nov., 1909.

1440 933,843. Metallurgical condenser.—**Woolsey M. Johnson,** La Harpe, Kans., assignor to The Continuous Zinc Furnace Company, Hartford, Conn. Filed Nov. 30, 1903. Issued Sept. 14, 1909.

A zinc condenser provided with cooling means and with electrical heating means. 7 claims.

1441 942,110. Electric furnace.—**Frederick T. Snyder,** Oak Park, Ills., assignor to Electric Metals Company, Chicago, Ills. Filed Sept. 25, 1906. Issued Dec. 7, 1909.

An electric furnace comprising a crucible base, a fluid-cooled wall surmounting said base, a tap opening being provided near the top of the crucible for drawing off the molten product therein, and a body of heat-insulating material extending through said cooled wall above the level of said tap, and having an outlet opening therethrough.

—Described in Met. & Chem. Eng., vol. 8, p. 49. Jan., 1910.

1442 944,774. Electric furnace for the continuous extraction of zinc from its ores.—**Eugene F. Cote** and **Paul R. Pierron,** Lyon, France. Filed May 14, 1907. Issued Dec. 28, 1909.

In a reducing furnace, a condenser comprising an outer casing communicating with the furnace, an inner casing arranged within the outer casing, and spaced apart from the walls thereof, an electrode at each end of the inner casing, the electrodes forming the terminals of an electric circuit, the electrodes being movable toward and from each other, and non-fusible material arranged between the electrodes for the purpose set forth.

—Described in Min. Mag., vol. 2, p. 204. Mar., 1910.

1443 946,688. Apparatus for production of zinc oxide.—**William Simm** and **Henry Simm,** Portico, near Prescott, England. Filed Oct. 1, 1907. Issued Jan. 18, 1910.

In an apparatus for producing zinc oxide electrically, the combination of a condensing chamber having suitable baffles, a hood connected therewith, and a suction fan for drawing the fumes into the hood and discharging them into the condenser, with an electrical furnace removably located beneath the hood and suitable detachable electric connections for the furnace, said connections including a choking coil. Patented also in England, No. 21,787 of 1906.

1444 950,877. Electric furnace.—**John Thomson,** New York, N. Y., assignor to Imbert Process Company, New York. Filed May 13, 1909. Issued March 1, 1910.

An electric furnace provided with a resister of a constant length having a plurality of elements and means for preserving a substantially constant contact resistivity between the elements irrespective of expansion or contraction due to thermal changes. 14 claims.

1445 950,878. Furnace.—**John Thomson,** New York, and **Francis A. J. FitzGerald,** Niagara Falls, N. Y., assignors to Imbert Process Co., New York. Filed May 13, 1909. Issued March 1, 1910.

A revolving electric furnace having a carbon resister as a central core. 15 claims.

1446 950,879. Electric furnace.—**John Thomson,** New York, N. Y., assignor to Imbert Process Company, New York. Filed Sept. 1, 1909. Issued March 1, 1910.

A resister for an electric furnace comprising a plurality of interlocking resistance elements. 34 claims.

1447 950,880. Electric furnace.—**John Thomson,** New York, N. Y., assignor to Imbert Process Company, New York. Filed Sept. 1, 1909. Issued March 1, 1910.

A revoluble electric furnace having a resister composed of interlocking members. 16 claims.

1448 950,881. Electric furnace.—**John Thomson,** New York, N. Y., assignor to Imbert Process Company, New York. Filed Sept. 1, 1909. Issued March 1, 1910.

An electric furnace having a self-supporting resister composed of a plurality of irregular blocks arranged in the form of a flat arch. 14 claims.

1449 950,882. Electric furnace.—**John Thomson,** New York, N. Y., assignor to Imbert Process Company, New York. Filed Sept. 1, 1909. Issued March 1, 1910.

A resister for an electric furnace comprising a plurality of blocks with their faces normally only partially in contact and so constructed and arranged that upon deformation under heat the area of contact between the blocks will increase.

1450 957,337. Electric furnace for smelting zinc.—**Hiram W. Hixon,** Philadelphia. Filed June 11, 1909. Issued May 10, 1910. 6 claims.

See also item 1338.

1451 957,058. Electric furnace for smelting zinc.—**Hiram W. Hixon,** Philadelphia. Filed Nov. 30, 1909. Issued May 3, 1910.

1452 964,268. Apparatus for smelting ore yielding a volatile metal.—**Woolsey McA. Johnson,** Hartford, Conn., assignor to The Continuous Zinc Furnace Company. Filed Nov. 9, 1906. Issued July 12, 1910.

Apparatus for smelting ores yielding a volatile metal, comprising in operative connection, an electric smelting furnace, a porous body of carbonaceous material, a condenser, and means for heating said body of carbonaceous material. 6 claims. See also item 1338.

1453 978,465. Electrometallurgical furnace.—**Francois Louvrier,** Mexico, Mexico. Filed Dec. 18, 1909. Issued Dec. 13, 1910.

A furnace comprising a plurality of reduction chambers electrically arranged in series, a preliminary crucible communicating with said reduction chambers and connecting them electrically, by way of the metal that it contains, means to prevent the prolonged contact of reduced metal with reduction slag and means for conducting an electric current through the reducing chambers and preliminary crucible. 8 claims.

1454 980,763. Electric furnace for the continuous extraction of zinc from its ores.—**Eugene Francois Cote** and **Paul Rambert Pierron,** Lyons, France. Filed Aug. 13, 1908. Issued Jan. 3, 1911. Six claims. 'Patented also in France, No. 385,018.

1455 989,169. Electrometallurgical furnace.—**Francois Louvrier,** Mexico, Mexico. Filed Dec. 18, 1909. Issued April 11, 1911.

A furnace comprising a furnace body, a condensing chamber built up within the furnace body in such manner as to divide the interior thereof into two separate and distinct reduction chambers, and provided with openings through the upper parts of its walls to allow inflow of volatilized metals from the reduction chambers; means for charging the reduction chambers, and means for reducing the charge.

1456 1,006,876. Metallurgy of zinc ores and compounds.—**Augustin L. J. Queneau,** Overbrook, Pa., assignor to Queneau Electric Zinc Furnace Corporation, Philadelphia. Filed Jan. 7, 1910. Issued October 24, 1911.

The method of reducing zinc ores and compounds which consists in establishing within a reducing chamber a fluid resister, introducing into the chamber the zinc ore charge, its reducing constituent being not materially in excess of that required for the reduction, maintaining the temperature of the charge at the reducing point by passing an electric current through the resistor, and tumbling the contents of the chamber in the presence of a highly liquid slag. 30 claims.

—Described in Met. & Chem. Eng., vol. 9, p. 662. Dec., 1911.

1457 1,006,877. Metallurgy of zinc.—**Augustin L. J. Queneau,** Philadelphia, Pa., assignor to Queneau Electric Furnace Company, Philadelphia. Filed June 8, 1911. Issued Oct. 24, 1911.

An electric furnace for the metallurgy of zinc ores and compounds, comprising a reducing chamber, a fluid resistor therein and means for heating said fluid resistor electrically, the electric current being introduced into the fluid resistor and taking its exit therefrom through the intermediacy of a portion of the furnace lining consisting of a mixture of refractory material and carbonaceous material constituting an electrical conducting body of the first order. 10 claims. Patented also in England, No. 19,305 of 1911; in France, No. 445,750.

1458 1,030,349. Metallurgy of zinc.—**Charles V. Thierry,** Paris, France. Filed Oct. 6, 1911. Issued June 25, 1912.

Consists in maintaining in an electric furnace from which air is excluded from the reducing zone, a composite charge composed of commercial metallic oxides and carbon, the said elements being electrically heated and the nature of the oxide being such that when subjected to an adequate temperature in the presence of carbon, it will volatilize; the oxide and the carbon being charged in such relative proportions that the reaction will convert the entire charge to the forms of fumes, gases, vapors and a relatively small proportion of ashy or sintered residue, said volatilized products continuously escaping from the reaction chamber as and when produced. 6 claims. Patented also in England, No. 19,973 of 1911.

—Described in Met. & Chem. Eng., vol. 10, p. 490-491. Aug., 1912.

1459 1,030,350. Metallurgy of zinc.—**Charles V. Thierry,** Paris, France. Filed Oct. 6, 1911. Issued June 25, 1912.

In the metallurgy of zinc, the placing and maintaining of a composite charge of commercially pure oxide of zinc and of carbon direcly upon a separate carbon resistor of an electric furnace, from which air is excluded, the relative proportions of the charged materials being such that when a sufficient current is passed through the resistor to produce reaction in the superimposed oxide of zinc and the carbon they will be completely transmuted into fumes, gases, vapors and inert ashy or sintered residue, the volatilized products automatically passing from the reducing zone, as and when produced, but the residue remaining upon, in or beneath the resistor until otherwise removed. 12 claims. Patented also in England, No. 20,913 of 1911.

—Described in Met. & Chem. Eng., vol. 10, p. 490-491. Aug., 1912.

1460 1,030,351. Metallurgy of zinc.—**Charles V. Thierry,** Paris, France. Filed Nov. 2, 1911. Issued June 25, 1912.

A process for the extraction of zinc from blue-powder produced during zinc-smelting, which comprises treating the said powder with a substance which acts on the covering of the particles thereof to form a compound soluble in water or other liquid, and subsequently consolidating said particles. 9 claims. Patented also in England, No. 21,014 of 1911; in France, No. 439,143.

—Described in Met. & Chem. Eng., vol. 10, p. 491. Aug., 1912.

1460a 1,051,512. Ore-reducing furnace.—**Peter Evert Peterson,** Butte, Mont. Filed May 10, 1912. Issued Jan. 28, 1913.

See also item 1332.

1461 1,057,878. Production of zinc and the like.—**Antoine Bonaventure Pescatore,** London, England. Filed Nov. 20, 1911. Issued April 1, 1913.

A process for the production of zinc and the like in shaft or like blast furnaces which consists in providing a limited supply of air for the furnace, such that the combustion gases in the reduction zone are kept free of oxygen and carbonic acid gas and at the same time increasing the temperature in this zone by electric heating as set forth. 10 claims. Patented also in England, No. 29,839 of 1910; in France, No. 436,650.

1462 1,059,342. Process for reducing zinc oxides.—**Charles F. Burgess,** Madison, Wis. Filed Oct. 8, 1909. Issued April 22, 1913.

The process of reducing zinc oxide which consists in electrically heating said oxide to a temperature sufficient to produce volatilization in one chamber, simultaneously heating a mass of carbon in the second chamber and conducting the vapors of the zinc oxide from said first chamber to said second chamber. 19 claims. See also item 1386.

1463 1,064,992. Metallurgy of zinc.—**Augustin L. J. Queneau,** Philadelphia, Pa., assignor to Queneau Electric Zinc Furnace Company, Philadelphia. Filed April 2, 1909. Issued June 17, 1913.

An electric furnace, having a rotary main body chamber, provided with an interior peripheral lining having a series of longitud-

inal courses of solid peripheral conductors forming a part of said lining and separated from each other by longitudinal courses of solid peripheral non-conductors, said conductors having a break in their electric conductivity and being bridged successively at the bottom of the chamber and across said break by molten resisting material. See also item 1326.

1464 1,080,862. Electric zinc furnace with integral condenser— **John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued Dec. 9, 1913. 12 claims.

1465 1,080,863. Electric zinc furnace with integral condenser. —**John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued Dec. 9, 1913. 23 claims.

1466 1,080,864. Electric zinc furnace with integral compound condenser.—**John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued Dec. 9, 1913. 14 claims.

1467 1,080,865. Electric furnace with integral condenser.—**John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued Dec. 9, 1913. 17 claims.

1468 1,080,866. Electric zinc furnace with integral condenser.— **John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued Dec. 9, 1913. 18 claims.

1469 1,080,912. Method of electrically smelting volatile metals.— **Woolsey McA. Johnson,** Hartford, Conn. Filed Jan. 17, 1911. Issued Dec. 9, 1913.

The method of smelting ores yielding a volatile metal, which consists in electrically heating a charge proportioned to yield a fusible slag, conducting the volatile reaction products into contact with carbon heated to its temperature of maximum reductivity, continuously replacing the carbon and condensing the metal. 17 claims.

1470 1,086,414. Electric zinc furnace with integral condenser.— **John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued Feb. 10, 1914. 20 claims.

1471 1,086,415. Electric zinc furnace with integral condenser.— **John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Isissued Feb. 10, 1914. 15 claims.

1472 1,086,416. Electric zinc furnace with integral compound resistors and compound condensers.—**John Thomson,** New York, N. Y. Filed Jan. 2, 913. Issued Feb. 10, 1914. 16 claims.

1473 1,086,417. Electric zinc furnace with integral condenser.— **John Thomson,** New York, N. Y. Filed April 14, 1913. Issued Feb. 10, 1914. 20 claims.

1474 1,086,418. Universal electric zinc furnace with integral condenser.—**John Thomson,** New York, N. Y. Filed May 8, 1913. Issued Feb. 10, 1914. 15 claims.

1475 1,088,496. Electrical heating device for metallurgical furnaces.—**Utley Wedge,** Ardmore, Pa. Filed June 19, 1912. Issued Feb. 24, 1914.

1476 1,090,427. Electric zinc furnace with integral condenser.—**John Thomson,** New York, N. Y. Filed Jan. 2, 1913. Issued March 17, 1914.

In an electric zinc furnace, a grate upon which a bed-of-carbon resistor is supported, the resistor being arranged to act upon a charge when the latter is placed in the furnace. 30 claims.

1477 1,090,428. Electric zinc furnace with integral condenser.—**John Thomson,** New York, N. Y. Filed April 14, 1913. Issued March 17, 1914.

An electric zinc furnace essentially comprising compound parallel porous resistors adapted to act upon charge material disposed along one of the vertical sides of each resistor, and fume condensing systems disposed along vertical sides of said resistors opposite to the zones of the reaction. 30 claims.

1478 1,092,764. Electric furnace for metallurgical purposes.—**Henry H. Buckman, Jr.,** Indianapolis. Filed June 30, 1913. Issued April 7, 1914.

See also item 1291.

1479 1,099,211. Process of and apparatus for producing zinc and other similar metals.—**Heinrich Specketer,** Griesheim-on-the-Main, Germany. Filed May 6, 1912. Issued June 9, 1914.

The process of producing zinc and other similar metals, which consists in charging a conductive mixture of zinciferous material and reducing agents into a furnace, directing an electric current through this mixture which acts as resistance, and turning over this mixture while it is maintained in an unsmelted condition so that its lowest layers are replaced from time to time without leaving the furnace by other portions of the mixture. 7 claims. See also items 1339 and 1404.

1480 1,110,359. Electric zinc furnace with integral condenser.—**Charles Victor Thierry,** Paris, France. Filed May 21, 1913. Issued Sept. 15, 1914.

An electric zinc furnace having a fume condensing system contained in the longitudinal side-walls and sole or bottom of the reaction chamber. Patented also in England, No. 7,953 of 1913; in France, No. 456,180. See also item 1334.

1481 1,121,874. Zinc furnace.—**Otto Ernst Ruhoff,** Madison, Wis. Filed March 26, 1914. Issued Dec. 22, 1914. 8 claims.

1482 1,122,663. Electric zinc furnace with integral condenser.—**Charles Victor Thierry** and **Michel Thierry,** Paris, France. Filed May 21, 1913. Issued Dec. 29, 1914.

An electric zinc furnace having a resistor whose side surfaces are partially retained by spaced plates, a sump directly beneath the resistor and by means of which the said resistor is sustained. 13 claims.

1483 1,122,664. Electric zinc furnace with integral condenser.—**Charles Victor Thierry** and **Michel Thierry,** Paris, France. Filed May 21, 1913. Issued Dec. 29, 1914.

1484 1,146,075. Process of treating zinc-bearing materials.—**Woolsey McA. Johnson,** Hartford, Conn., assignor to The Continuous Furnace Company, Hartford. Filed June 27, 1913. Issued July 13, 1915.

A cyclical process of treating a charge of zinc-bearing material low in sulphur and containing silica, which consists in electrically heating the said charge in presence of molten iron, producing thereby metallic zinc and a ferruginous silicate slag, condensing the evolved zinc vapors recovering iron from the said ferruginous silicate slag, and utilizing the reduced iron to further reduce quantities of zinc-bearing material. See also item 1393.

1485 1,150,271. Electric reduction of zinc ores.—**Woolsey McA. Johnson,** Hartford, Conn., assigner to The Continuous Zinc Furnace Company, Hartford. Filed Oct. 17, 1912. Issued Aug. 17, 1915.

In the electric reduction of complex zinc ores, including in their analysis sulphur, lead and calcium or barium, preliminary calcining said ores to the substantial elimination of sulphates with the exception of sulphate of lead and such sulphates of calcium and barium as are present, and then reducing the residual sulphates to sulphides. 5 claims. See also item 1382.

1486 1,153,786. Reduction of metallic oxides and the like.—**Frank William Highfield,** Caversham, England. Filed March 15, 1915. Issued Sept. 14, 1915.

In a furnace for the recovery of zinc from an oxidized condition thereof, the combination of a wall of material that is porous to carbon monoxide at the working temperature of the furnace and that divides the said zinc in its oxidized condition from the atmosphere of the furnace, electrically heated carbon adjacent to the said wall to heat it and to provide a furnace atmosphere of carbon monoxide, a grate beneath the carbon to support it, a chamber beneath the grate to receive the reduced metal and a cooling chamber in direct communication with the said receiving chamber. See also item 1387.

1487 1,160,244. Treating materials in electric furnaces.—**Edward Salomon Berglund,** Trollhattan, Sweden. Filed April 21 1915. Issued Nov. 16, 1915.

See also item 1397.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 259. Feb. 29, 1916.

1488 1,165,371. Duplex smelting process.—**Woolsey McA. Johnson** and **Edwin W. Hale,** Hartford, Conn., assignors to The Continuous Zinc Furnace Company, Hartford. Filed March 16, 1914. Issued Dec. 21, 1915.

A process for reducing high-grade zinc ores consisting in obtaining the zinc-bearing material in a state having a low sulphur content then forming a retort charge thereof by the addition of carbon, then heating said mixture in a retort externally heated to a temperature rising to about 1150° C., as a maximum, thereafter utilizing the residue from said retort together with additional carbon for preparing another mixture, and then obtaining the ultimate metallic values by electrically developing heat within the charge while enclosed in an air-excluding container.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 259. Feb. 29, 1916.

1489 1,167,176. Smelting of ores and apparatus therefor.—**Frank William Highfield,** Caversham, England. Filed Feb. 23, 1915. Issued Jan. 4, 1916.

The process for the reduction of complex sulphide ores which consists in roasting the ore to remove the sulphur therefrom, mixing the roasted ore with a reducing agent and heating the charge electrically in a reducing atmosphere to a temperature of 950° C. at which the zinc content is volatilized but the lead is not and the latter is thereby separated in a liquid condition from the former, separating the molten lead from the residual matte and heating said matte electrically to a temperature of 1300° C. for the formation of silicious slags and subjecting the matte of copper and iron sulphides while it is still liquid to the action of a direct current to promote separation of its iron and copper contents and decomposition of the copper and iron sulphides. Patented also in England, Nos. 4,937 and 2,728 in 1914; in France, No. 478,778.

1490 1,167,998. Process of obtaining metals, such as lead or zinc, in an electric furnace.—**Alois Helfenstein,** Vienna, Austria-Hungary. Filed Feb. 2, 1914. Issued Jan. 11, 1916.

A process for obtaining metal vapors, especially those of zinc and lead, from ores in an electric furnace, which consists of preheating the charge before the distillation process takes place, exhausting the gases and vapors developed in the preheating zone to free the metallic vapors from gases favoring oxides or formation of metallic dust and exhausting part of the carbon oxides and metal vapors generated in the distillation zone. Patented also in France, No. 468,445. See also item 1333.

1491 1,184,520. Electric furnace permitting the extraction in a state of purity of zinc from its ores.—**Eugene Francois Cote** and **Paul Rambert Pierron,** Lyons, France, assignors to Societe Anonymne pour l'Electrometallurgie du zinc. Filed July 24, 1914. Issued May 23, 1916.

An apparatus for extracting zinc from ores in a state of purity, comprising a furnace for melting the ores, and a refining furnace into which the zinc vapors from the melting furnace are delivered, said refining furnace being provided with means for condensing the zinc vapors in the form of drops or powder and with means for redistilling the zinc-drops or powder, whereby the metal will be refined successively with the production thereof while at a temperature next to the point of volatilization thereof. 15 claims. Patented also in England, No. 14,192 of 1914; in France, No. 474,321.

1492 1,193,633. Electric fuming or distilling furnace and condenser therefor.—**John Thomson,** New York, N. Y., assignor to John Thomson Press Company, Jersey City. Filed Oct. 2, 1915. Issued Aug. 8, 1916. 19 claims.

See also item 1329.

1493 1,197,137. Method of reducing metals.—**Robert J. McNitt,** Perth Amboy, N. Y., assignor to the Roessler & Hasslacher Chemical Company, New York. Filed Jan. 2, 1913. Issued Sept. 5, 1916.

A method of reducing metallic compounds to their metals by electrolysis consisting in raising the boiling point of said metals by pressure on the molten electrolyte while maintaining the temperature of the electrolyte below its boiling point at atmosphere pressure. 12 claims.

1494 1,207,127. Method of and apparatus for obtaining zinc.—**Edward S. Berglund,** Trollhattan, Sweden, assignor to Trollhattans Elektrothermiska Aktiebolag, Trollhattan, Sweden. Filed Sept. 15, 1914. Issued Dec. 5, 1916.

In extracting zinc in an electric furnace the method of reducing and purifying the metallic vapors developed in the furnace, consisting in passing said vapors after leaving the furnace and on their way to the condenser, over a layer of reducing material, without passing them through such material and heating them above the condensing temperature. 6 claims.

1495 1,213,180. Recovery of zinc.—**Charles H. Fulton,** Cleveland, Ohio. Filed July 17, 1916. Issued Jan. 23, 1917.

The method of recovering zinc, which consists in (1) mixing the ground and calcined ore with a reducing agent and a binder of such a character and in such proportions as will form briquets formed from such mixture to maintain their form and volume during the process of distillation, (2) forming such ore mixture into compact briquets under pressure, (3) preheating such briquets to drive off the volatile contents of the binder and convert the latter into coke, (4) interposing said briquets as a continuous resistor between the electrodes of a closed electric furnace and passing a current of electricity through them to heat them to a distilling temperature, and (5) recovering the zinc from the zinc vapor evolved by the distillation of the briquets. Patented also in England, No. 106,050 of 1916. See also item 1359.

—Described in Jour. Soc. Chem. Ind., vol. 36, p. 343. March 31, 1917.

1496 1,214,842. Electric zinc-distilling furnace and condenser for producing blue powder.—**John Thomson,** New York, assignor to John Thomson Press Co., Jersey City, N. J. Filed Jan. 28, 1916. Issued Feb. 6, 1917.

An electric furnace for distilling spelter having attached condensers, adapted to receive zinc fume from a chamber formed by a ported septum and an overlying roof, the rate of heat radiation from said roof being controllable, whereby the temperature of the hot fume from the ported septum is reduced, by contact with the roof, prior to entering the condenser.

1497 1,219,193. Condenser in the metallurgy of zinc.—**John Thomson**, New York, N. Y., and **Francis A. J. FitzGerald**, Niagara Falls, N. Y., assignors to John Thomson Press Company, Jersey City, N. J. Filed June 21, 1916. Issued March 13, 1917.

In the metallurgy of zinc, a condenser, set at a decline from the source of fume-supply and in which liquid metal is produced but not retained, combined with a separate underlying receptacle disposed in such manner that it can be removed without disturbing the said condenser.

1498 1,219,194. Electric zinc-distilling furnace.—**John Thomson**, New York, N. Y., and **Francis FitzGerald**, Niagara Falls, N. Y., assignors to John Thomson Press Company, Jersey City, N. J. Filed June 21, 1916. Issued March 13, 1917.

In an electric furnace, a suspended resistor embraced by an overhead horizontal and vertical side septums, so disposed within the main chamber as to provide fume passages between the furnace walls and along the top of the horizintal septum. 15 claims.

1498a 1,220,111. Apparatus for refining metals by heating.—**Alois Helfenstein**, Vienna, Austria. Filed June 5, 1912. Issued March 20, 1917.

A long tubular furnace provided with charging openings and adapted to receive a thin metal bath, means for heating said bath by fuel, water cooled conductors extending with their ends into said bath within said furnace through the bottom thereof for short circuiting said bath, means for imparting to said furnace an intermittent rotary movement around its longitudinal axis, and means for supplying energy to said conductors. See also item 1274.

1499 1,231,084. Apparatus for producing zinc and other similar metals.—**Heinrich Specketer**, Griesheim-on-the-Main, Germany. Filed Jan. 29, 1915. Issued June 26, 1917.

A rotary electric furnace provided with at least one partition disposed longitudinally in the furnace to divide the same into at least two reduction chambers. 9 claims. Patented also in Germany, No. 290,643.

1500 1,236,395. Method and apparatus for extracting zinc.—**Edward Salomon Berglund**, Trollhattan, Sweden. Filed Feb. 15, 1916. Issued Aug. 14, 1917.

In the electro-thermic extraction of zinc, condensing the zinc vapors, precluding contact between air and zinc powder formed and re-introducing the zinc powder into the furnace and thereby increasing the content of zinc in the furnace gases. 7 claims. See also item 1302.

1501 1,242,337. Electrical distilling apparatus.—**Charles H. Fulton,** St. Louis, Mo., assignor to Metallurgical Laboratories, Inc., Chicago, Ills. Filed Dec. 7, 1916. Issued Oct. 9, 1917. 34 claims. Patented also in England, No. 111,835 of 1917.

—Described in Met. & Chem. Eng., vol. 18, p. 539-40. May 15, 1918.

1502 1,242,339. Process for distilling metallic ores.—**Charles H. Fulton** and **Thomas M. Bains, Jr.,** St. Louis, Mo., assignors to Metallurgical Laboratories, Inc., Chicago, Ills. Filed Jan. 24, 1917. Issued Oct. 9, 1917.

A distilling process, characterized by forming metallic ore or metal-bearing material into briquets that will retain their substantially original form and volume when subjected to a distilling temperature, causing said briquets to travel through a distilling chamber, and subjecting said briquets to heat while they are in said chamber. 16 claims. Patented also in England, No. 112,924 of 1917.

—Described in Met. & Chem. Eng., vol. 18, p. 539-40. May 15, 1918.

1503 1,242,340. Apparatus for distilling metallic ores and metal-bearing materials.—**Charles H. Fulton** and **Thomas M. Bains,** St. Louis, Mo., assignors to Metallurgical Laboratories, Inc., Chicago, Ills. Filed Jan. 24, 1917. Issued Oct. 9, 1917. 22 claims.

—Described in Met. & Chem. Eng., vol. 18, p. 539-40. May 15, 1918.

1504 1,242,341. Electric furnace.—**Charles H. Fulton,** St. Louis, Mo., assignor to Metallurgical Laboratories, Inc., Chicago, Ills. Filed Feb. 23, 1917. Issued Oct. 9, 1917. 19 claims.

—Described in Met. & Chem. Eng., vol. 18, p. 539-40. May 15, 1918.

1505 1,244,504. Continuous zinc smelter.—**Woolsey McA. Johnson,** Hartford, Conn. Filed Feb. 4, 1915. Issued Oct. 30, 1917.

A unitary smelting apparatus combining an electric furnace having heat-insulated walls; a preheating retort having heat-conducting thin walls and connected with said furnace whereby smeltable material may be preheated in said retort and passed directly into said furnace without being exposed to air; and a fuel-burning furnace arranged to heat said retort; and a condenser adapted to receive all the gaseous products from said furnace.

—Described, with diagr., in Met. & Chem. Eng., vol. 18, p. 654. June 15, 1918.

1506 1,255,066. Process and apparatus for producing zinc and the like.—**Filip Tharaldsen,** Christiania, Norway. Filed Aug. 18, 1916. Issued Jan. 29, 1918.

The process for the continuous production of zinc and other volatile metals from their ores comprising introducing the charge in the shape of an approximately horizontal layer continuously into an electric radiation furnace, heating the surface of the layer by means of radiant electric heat to liberate the vapors of the volatile metal principally in said surface, conducting said vapors through a separate outlet into a condenser, and removing the residues of the charge. 6 claims.

—Described in Met. & Chem. Eng., vol. 18, p. 654. June 15, 1918.

1506a 1,264,628. Distilling process for recovering metals from ores and metal-bearing materials.—**Charles H. Fulton,** St. Louis, Missouri.

Forms the metal-bearing material into objects that will retain their approximately original form and volume when subjected to a distilling temperature, arranging one or more of said objects in a chamber, and subjecting said object or objects to heat of a sufficiently high temperature to distill the metal contained in same.

1507 1,256,802. Process of extracting zinc from its ores.—**Edvin Andreas Johansson,** Trollhattan, Sweden, assignor to Societe Anonyme Metallurgique Precedes De Laval, Brussels, Belgium. Filed March 22, 1912. Issued Feb. 19, 1918.

The method of extracting zinc from its ores, which consists in introducing into an electric resistance furnace a charge containing sufficient carbon to combine with the oxygen of the ore to form carbon monoxide, passing an electric current through a portion of said ore to produce various degrees of heat in different parts of said ore, causing the carbon dioxide formed in the cooler parts of the charge to successively penetrate the hotter parts of the ore whereby the remaining unaltered carbon will reduce it to carbon monoxide.

—Described in Met. & Chem. Eng., vol. 18, p. 654. June 15. 1918.

1507a 1,265,973. Electric zinc-distilling furnace and condenser.—**John Thomson,** New York. Filed January 19, 1916. Issued May 14, 1918.

An electric furnace for distilling spelter having a condenser in which there is a plurality of staggered plates around the ends of a portion of which both fume and condensed metal may flow but around another portion of which only fume can flow. 7 claims.

1507b 1,266,808. Method of converting zinc powder into liquid zinc.—**Sven Huldt,** Stockholm, Sweden, assignor to Norsk Elektrisk Metalindustri Aktieselskap, Sarpsborg, Norway. Filed April 3, 1917. Issued May 21, 1918.

The method of converting zinc powder into liquid zinc, consisting in heating the zinc powder to the melting temperature of the zinc and subjecting the powder to a rubbing operation. Patented also in England, No. 105,558 of 1917.

1507c 1,271,267. Electrothermic extraction of zinc.—**Edward Salomon Berglund,** Trollhättan, Sweden. Filed July 25, 1917. Issued July 2, 1918.

In electrothermic extraction of zinc, conducting zinc-containing vapors simultaneously from several smelting furnaces to one common condenser, and shutting off the communication from one of the said smelting furnaces without disturbing the working of the remaining furnaces. Patented also in England, No. 109,435 of 1917.

1507d 1,286,100. Electric furnace.—**B. Raeder.** Issued Nov. 26, 1918.

Especially adapted to the production of zinc.

Great Britain

1508 12,432 of 1890. Improvements in the manufacture or production of zinc from the oxidized ores of zinc.—**T. Parker** and **A. E. Robinson,** Wolverhampton.

The ore, if a sulphide or carbonate, is first roasted and then mixed with sufficient carbon in the form of charcoal, pitch, coke, or tar to effect its reduction and give proper electrical conduction.

1509 472 of 1900. Process and apparatus for obtaining zinc from its ores.—**C. Casoretti** and **F. Bertani,** Milan.

Furnace for combined retort and electric smelting. Patented also in Germany, No. 129,889.

—Described in Zeits. f. angewandte Chem., vol. 15, pp. 437-438. May 6, 1902.

1510 23,756 of 1902. Process of extracting zinc and other volatile metals from their ores.—**Trollhattans Elektriska Kraftaktiebolag,** by **F. W. Howorth,** London.

A zinc distilling furnace in which the charge is fed down a sloping surface, exposed to the heat of an electric arc, the zinc being distilled off, and the remainder of the charge being melted and run off to the bottom. Patented also in France, no. 325,895.

1511 9,932 of 1903. Electric smelting furnace.—**Trollhattans Elektriska Kraftactiebolag,** Stockholm, Sweden.

Improvements in the inventor's furnace for smelting by means of the reflected heat of the electric arc, the charge slowly falling down an inclined surface.

1512 4,058 of 1904. Treating zinc blende and other substances containing zinc.—**W.** and **H. Simm,** Prescott, England. **R. Storey** and **J. S. Sellers,** Liverpool.

"The ore is heated in an electric furnace of the type described in 4,059 of 1904, into which air is subsequently admitted. The zinc oxide produced is condensed, and the sulphur dioxide or other gases utilized."—J. S. C. I.

1513 4,059 of 1904. Electric furnace.—**W. and H. Simm,** Prescott, England, **R. Storey** and **J. S. Sellers,** Liverpool.

"An electric resistance furnace with three or more cross-bars of carbon, connected alternately in parallel. The spaces between the bars are filled with a mixture of ground silica and carbon which serves as the resistance."—J. S. C. I.

1514 16,205 of 1904. Electric furnaces and extraction of zinc by means of same.—**A. Edelmann** and **N. Wallin,** Charlottenburg.

—Described in Jour. Soc. Chem. Ind., vol. 23, p. 1035. Nov. 15, 1904.

1515 15,818 of 1906. Electric zinc furnace.—**K. Kaiser,** Berlin.

"In electric furnaces such as are intended for reducing zinc from zinciferous pyrites, using a blast of reducing gas instead of adding carbon to the charge."—E. & M. J.

1516 18,712 of 1906. Electric furnace.—**F. T. Snyder,** Chicago.

"An electric furnace for smelting zinc ores that are not suitable for distilling owing to high lime contents."—E. & M. J.

1517 24,096 of 1906. Process for the direct production of metallic zinc from zinc sulphide, and the subsequent utilization of the sulphur and regaining of the flux, desulphurating the zinc sulphide.—**Rhenisch-Nassauische Bergwerks und Huetten—A. G.,** Stolberg, **W. Borchers** and **A. Graumann,** Aix-la-Chapelle.

"Pulverized and unroasted zinc sulphide is mixed with finely divided metallic iron. The mixture is continuously fed into an electric furnace, preferably of the resistance type in which the charge forms the resistance, where at a temperature between 1000° and 1500° C., it is decomposed into metallic zinc, the vapor of which is condensed in any usual way, and ferrous sulphide, which is tapped off at intervals in the molten state...'—J. S. C. I.

—Described in Jour. Soc. Chem. Ind., vol. 26, pp. 98-99. Feb. 15, 1907.

1518 22,283 of 1907. Electric furnace for the continuous extraction of zinc from its ores.—**Eugene F. Cote** and **Paul R. Pierron,** Lyons, France.

1519 18,653 of 1908. Electric furnace for the continuous distillation of zinc from its ores.—**Eugene F. Cote** and **Paul R. Pierron,** Lyons, France.

1520 25,979 of 1909. Method and furnace for the reduction of zinc.—**A. R. Lindblad** and **O. Stalhane,** Ludvika, Sweden. Nov. 10, 1909.

1521 16,602 of 1915. Rotary electric furnace for the production of zinc and other metals.—**F. Cochlovius,** Buchschlag, Hessen, Germany.

—Described in Jour. Soc. Chem. Ind., vol. 36, p. 343. March 31, 1917.

1522 10.613 of 1916. Refining zinc by volatilization in a continuous electric radiating furnace.—**S. Huldt,** Sweden.

—Described in Min. Mag., vol. 16, p. 224. April, 1917.

1522a 106,050 of 1916. Distillation of zinc in the electric furnace. —**D. B. Jones.**

"In the distillation of zinc in a closed furnace for obtaining zinc or zinc oxide, the current is passed through a series of resistive zinc ore briquettes of such character as to be unchanged in form by the distillation.

—Described in Chem. Abst., vol. 11, p. 2434. Sept. 10, 1917.

1523 4,954 of 1917. Reduction of zinc.—**Norsk Elektresk Metalindustri,** Sarpsborg, Norway.

Converting zinc powder into liquid zinc in a rotating electric furnace, the rotating action serving to remove the external oxide coating of the zinc particles.

1524 109,435 of 1917. Method of and arrangements for extracting zinc by the electro-thermal process.—**E. Berglund,** Trollhattan, Sweden.

France

1525 330,665. Electrochemical treatment of the minerals of zinc or other volatile metals, for the extraction of the metals which they contain.—**A. Salgues.** March 28, 1903.

Relates to an electric furnace rendered tight by the cooling of its external parts; the vapors are thus condensed and leakages stopped.

—Described in Jour. Soc. Chem. Ind., vol. 22, p. 1094. Oct. 15, 1903.

1526 343,114. Direct extraction of zinc from its ores.—**A. Rodriguez,** Bruna. April 20, 1904.

"Zinc ores are mixed with carbon and the mixture is heated under pressure in an electric furnace. It is stated that the zinc may be thus obtained in the melted state instead of as vapor."—J. S. C. I.

1527 382,872. Electric zinc furnace.—**G. H. Gin.** Oct. 14, 1907.
—Described, with diagr., in Jour. Soc. Chem. Ind., vol. 27, p. 289. March 31, 1908.

See also item 1364.

1528 397,631. Process of treating blende for the manufacture of zinc sulphide.—**Eugene F. Cote** and **P. R. Pierron.** Feb. 28, 1908.

"Zinc blende is melted with iron in an electric furnace, and the zinc vapor produced is either treated at once with H_2S to convert it into sulphide, or it is first transformed into oxide."

—Described in Jour. Soc. Chem. Ind., vol. 28, p. 708. July 15, 1909.

1529 420,922. Electric furnace for the treatment of zinc ores or secondary metallurgical products.—**Societa di Monteponi.** Sept. 30, 1910.

1530 441,697. Method of extracting zinc from its ores.—**Soc. Anon. Metallurg. Proc. de Laval.** March 23, 1912.

The charge, containing excess of carbon, is fed from the sides into an electric resistance furnace, the electrodes, and the outlet for the gases formed being in the middle.

1531 480,633. Extraction of zinc.—**E. S. Berglund.** Jan. 7, 1916.

"The bulk of the zinc vapor is condensed as liquid metal and the remainder as zinc dust which is subsequently volatilized out of contact with air and re-condensed in the same system."

—Described in Jour. Soc. Chem. Ind., vol. 36, p. 145. Feb. 15, 1917.

Germany

1532 128,535. Smelting silicious zinc ores in the electric furnace. —**Alfred Dorsemagen,** Aix-la-Chapelle. Dec., 1900.

—Described in Zeits. f. angewandte Chem., vol. 15, p. 185. Feb. 25, 1902.

1533 132,205. Recovery of zinc, lead, copper, nickel or cobalt from sulphide ores or other materials.—**Friederich Darmstaedter,** Darmstadt, Germany. Sept. 19, 1899.

—Described in Zeits. f. angewandte Chem., vol. 15, pp. 632-33. June 24, 1902.

1534 148,439. Process for the continuous distillation of zinc in the electric furnace.—**Gustave de Laval,** Stockholm, Sweden, and **Trollhattans Elektriska Aktiebolag.** April 30, 1901.

See also next patent; also item 1400.

—Described in Zeits. f. angewandte Chem., vol. 17, p. 428. April 1, 1904.

1535 157,603. Continuous distillation of zinc in the electric furnace.—**Gustave de Laval.** April 30, 1901.

Modification of preceding patent.

1536 158,545. Recovery of zinc in an electric furnace, using a hollow electrode surrounded by the charge.—**Edelmann** and **Wallin,** Charlottenburg, Germany. July 24, 1903.

—Described, with diagr., in Zeits. f. angewandte Chem., vol. 18, pp. 668-69. April 28, 1905.

1537 189,313. Process for the recovery of iron and zinc from zinciferous iron ores and smelter products, such as roasted pyrites, by treatment in the electric furnace.—**K. Kaiser,** Berlin. July 20, 1905.

—Described in Zeits. f. angewandte Chem., vol. 21, p. 166. Jan. 24, 1908.

1538 200,668. Continuous recovery of zinc in fluid state in an electric furnace with heated condensation chamber.—**Eugene F. Cote** and **Paul R. Pierron,** Lyons, France. March 1, 1907.

See also item 1369.

—Described, with diagr., in Zeits. f. angewandte Chem., vol. 21, p. 1992. Sept. 18, 1908.

1539 206,148. Electric furnace for the continuous recovery of zinc from ores.—**Eugene F. Cote** and **Paul R. Pierron,** Lyons, France.

See also item 1354.

—Described, with diagr., Zeits. f. angewandte Chem., vol. 22, p. 546. March 19, 1909.

1540 203,085. Recovery of zinc from ores, using an electric induction furnace.—**Gustave Gin,** Paris. Dec. 5, 1907.

—Described in Zeits. f. angewandte Chem., vol. 22, pp. 844-45. April 30, 1909.

1541 208,451. Production of zinc oxide by the smelting of zinc ores and other zincy materials in the electric furnace.—**William** and **Henry Simm,** Prescott, England. Oct. 3, 1907.

—Described in Zeits. f. angewandte Chem., vol. 22, p. 885. May 7, 1909.

1542 210,030. Process and apparatus for recovery of zinc by precipitation process in the electric furnace.—**E. F. Cote** and **P. R. Pierron.** Sept. 16, 1908.

See also item 1363.

—Described in Zeits. f. angewandte Chem., vol. 22, p. 1465. July 16, 1909.

1543 232,928. Process and apparatus for the reduction of zinc ores in the electric furnace, using a fluid resistant.—**A. L. J. Queneau,** Philadelphia, Pa. May 15, 1909.

—Described in Zeits. f. angewandte Chem., vol. 24, p. 814. April 28, 1911.

1544 235,914. Production of zinc in the electric furnace.—**Alex. R. Lindblad** and **Otto Stalhane,** Ludvika, Sweden.

—Described, with diagr., in Zeits. f. angewandte Chem., vol. 24, p. 1493-94. Aug. 4, 1911.

1545 245,365. Recovery of metallic zinc from its ores by treating the dessicated or roasted ores with hydrofluoric acid or fluosilicic acid to form zinc fluoride, mixed with zinc oxide and smelted in an electric furnace.—**Gino Gallo,** Rome, Italy. Jan. 26, 1911.

1546 254,029. Recovery of zinc and similar metals in the electric furnace, using the charge as heat resistant—**H. Specketer,** Griesheim-am-Main, Germany. June 11. 1911. See also German Patent 282,795.
—Described in Zeits. f. angewandte Chem., vol. 26, pt. II, p. 56. Jan. 28, 1913.

1547 261,188. Process for the production of zinc, using a fluid slag bath.—**F. Tharaldsen,** Trondjem, Norway. March 12, 1912.
See also items 1337, 1405 and 1552.
—Described, with diagr., in Zeits. f. angewandte Chem., vol. 26, pt. II, p. 440. July 22, 1913.

1548 272,537. Process for the recovery of zinc or other easily volatilized metals.—**Roman von Zelewski,** Engis, Belgium. Dec. 8, 1912.
—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 301. May 8, 1914.

1549 275,904. Process for separation of copper, lead and zinc from their sulphide and oxide ores and by-products, by a combined roasting, smelting, volatilizing and leaching process.—**Wilhelm Borchers,** Aix-la-Chapelle, and **Wilhelm Menzel,** Hamburg, Germany. July 29, 1913.
—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 523. Sept. 4, 1914.

1550 282,141. Process for the electrothermic recovery of volatile metals, especially zinc.—**Max Breslauer,** Berlin. Jan. 30, 1913.
—Described in Zeits. f. angewandte Chem., vol. 28. pt. II, p. 143. March 19, 1915.

1551 282,795. Process for the production of zinc and similar metals.—**H. Specketer,** Griesheim, Germany. Feb. 6, 1914.
Modification of 254,029. The zinc is only partially recovered—about 70%—in the first furnace, and the process is completed in a smaller one.
—Described in Zeits. f. angewandte Chem., vol. 28, pt. II, p. 202. April 16. 1915.

1552 286,228 and 286,229. Process and apparatus for the production of zinc, using a fluid slag bath.—**F. Tharaldsen,** Trondjem, Norway. March 28 and 31, 1914.
Modifications of 261,188, above.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 185. Feb. 15, 1916.
—Described in Zeits. f. angewandte Chem., vol. 28, pt. II, p. 489. Sept. 24, 1915.

1553 286,557. Process and apparatus for cleaning the surface of a zinc bath in an electric furnace for refining zinc by distilliation.—**A/S Metalforedling,** Tronjhem, Norway. April 9, 1914.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 185, Feb. 15, 1916.

1554 288,616. Electric furnace for the recovery of zinc and other volatile metals.—**O. Schneemilch.** Dec. 12, 1913.
See also item 1353.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 426. April 15, 1916.

1555 288,684. Electric metallurgical furnace for the extraction of zinc and the like.—**Coswiger Braunkohlwerke G. m. b. H.,** Coswig, Anhalt, Germany. Jan. 19, 1913.
See also item 1352.
—Described in Jour. Soc. Chem. Ind., vol. 35, pp. 426-27. April 15, 1916.

1556 289,493. Method of condensing metallic vapors, especially zinc, in the electric furnace.—**A/S Metalforedling,** Tronjhem, Norway. March 27, 1914.
"The gases and metallic vapors pass from the furnace down inclined tubes sufficiently long to insure the condensation of the metal to the liquid state. Uptakes containing coke are provided for the escape of the non-condensable gases."
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 427. April 15, 1916.

1557 290,499. Furnace for the electrothermic extraction of zinc.—**A/S Metalforedling,** Tronjhem, Norway. April 5, 1914.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 606. May 31, 1916.

1558 290,690. Method of condensing metallic vapors, especially those of zinc, in the electric furnace.—**A/S Metalforedling,** Trondhjem, Norway. May 20, 1914.
The uptakes are filled with pieces of coke, so that they act as gas-cushions and equalize fluctuations of pressure in the furnace.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 606. May 31, 1916.

1559 291,492. Apparatus for the condensation of zinc vapor in the electric furnace.—**A/S Metalforedling,** Trondhjem, Norway. March 31, 1914.
—Described in Jour. Soc. Chem. Ind., vol. 35, p. 695. June 30, 1916.
—Described in Chem. Abst., vol. 11, p. 921. April 20, 1917.

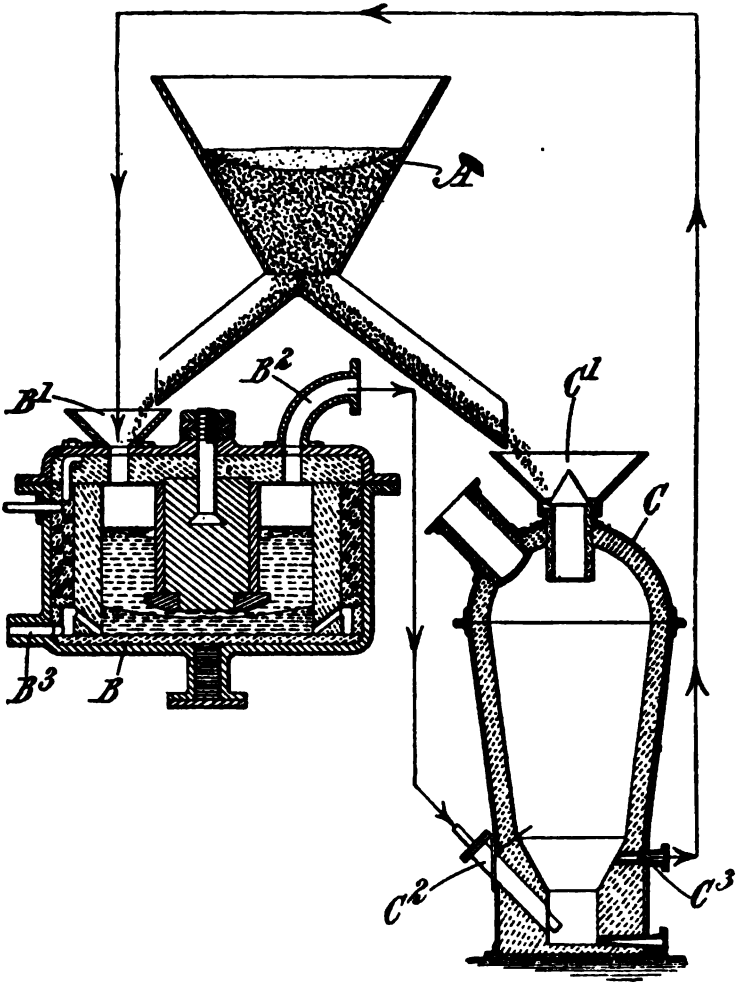
1560 292,471. Production of zinc.—**F. Tharaldsen,** Trondhjem, Norway. April 23, 1915.

The gases produced on treating the slag (see 286,228) are led into a condensing chamber connected with the furnace instead of into a separate chamber.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 850. Aug. 15, 1916.

1560a 307,293. Process for the recovery of zinc from zinc dust.—**Norsk Elektrisk Metalindustri Aktieselskap,** Sundloekken, Norway. Aug. 13, 1918.

—Abstract, in German. diagr. Zeits. f. angewandte Chem., vol. 31, p. 289. Sept. 27, 1918.



ASHCROFT'S APPARATUS FOR ELECTROLYSIS OF FUSED ZINC SULPHIDE
(See item 1616)

ELECTROLYSIS OF FUSED MATERIALS

See also items 1633, 1633a.

1561 The Ashcroft-Swinburne process. Eng. & Min. Jour., vol. 76, p. 162. Aug. 1, 1903.

1562 Beitrag zur Elektrolyse der Zinksalze.—**G. Nahnsen.** Berg. u. Huetten. Zeitg., vol. 50, pp. 393-97. Oct. 23, 1891.

1563 Chlorine smelting, with electrolysis.—**James Swinburne.** Electrician, vol. 51, pp. 495-96, 583-84. July 10, 24, 1903.

Paper before the Faraday Society describing the author's process for electrolyzing zinc or lead chlorides. Cost data.

—Abstract. Jour. Soc. Chem. Ind., vol. 22, p. 953. Aug. 31, 1903.

—Abstract. Electrochem. Ind., vol. 1, pp. 412-13. Aug., 1903.

1564 Chloro-electrolytic smelting. diagr. Electrochem. & Met. Ind., vol. 3, pp. 63-66. Feb., 1905.

1565 Demonstration zur Elektrolyse geschmolzener Salze.—**Richard Lorenz.** diagr. Zeits. f. Elektrochem., vol. 7, pp. 277-87. Nov. 15, 1900.

Electrolysis of fused salts. Paper at Seventh General Conference of the German Electrochemical Society. See also item 1574.

1566 Einige Worte ueber die Chlorzinkelektrolyse nach Dr. Hoepfner.—**E. Guenther.** Metall. u. Erz., vol. 10, pp. 206-7. Jan. 8, 1913.

—Abstract. Zeits. f. angewandte Chem., vol. 26, pt. II, p. 250. April 22, 1913.

1567 The electric smelting of complex sulphides.—**A. A. Beadle.** diagr. Eng. & Min. Jour., vol. 77, pp. 479-80. March 24, 1904.

A discussion of the principles underlying leaching and electrolysis of fused zinc salts.

1568 Electrolysis of fused materials containing zinc.—**Chun Hao Wang.** Columbia University, N. Y., 1914. 45 pp.

Thesis for Ph.D. degree. Review of existing literature, and report of experiments on electrolysis of aqueous zinc salt solutions, precipitation of zinc from fused baths, electrothermal treatment of zinc ores, determination of freezing points of several salts and their mixtures, etc.

—Abstract. Met. & Chem. Eng., vol. 12, p. 523. Aug., 1914

—Abstract. Chem. Abst., vol. 8, p. 3270. Oct. 10. 1914.

1569 Electrolysis of fused salts.—**A. Helfenstein.** Jour. Soc. Chem. Ind., vol. 19, p. 670. July 31, 1900.
—Abstract. Zeits. f. anorgan. Chem., vol. 23, pp. 255-316. 1900.

1570 The electrolysis of fused zinc chloride in cells heated externally.—**Julius L. F. Vogel.** illus., diagr. Faraday Soc., Trans., vol. 2, pp. 56-71. May, 1906.
—Abstract. Electrochem. & Met. Ind., vol. 4, p. 208. June, 1906.
—Abstract. Electrician, vol. 57, p. 305. June 8, 1906.
—Abstract. Jour. Soc. Chem. Ind., vol. 25, p. 595. June 30, 1906.
—Abstract. Sci. Abst. A., vol. 10, pp. 118-19. Feb., 1907.

1571 An electrolytic method for the reduction of blue powder.—**Warren F. Bleeker.** Amer. Electrochem. Soc., Trans., vol. 21, pp. 359-69. 1912.
—Abstract. The reduction of blue powder in zinc smelting. Min. Wld., vol. 36, pp. 951-52. May 4, 1912.
—Abstract. Met. & Chem. Eng., vol. 10, p. 300. May, 1912.

1572 Electrolytic preparation of zinc and lead.—**Richard Lorenz.** Zeits. f. anorgan. Chem., vol. 10, pp. 78-116. 1895. (In German.)
—Abstract. Jour. Chem. Soc., vol. 70, pt II, pp. 22-24. 1896.

1573 Die Elektrolyse geschmolzener Salze.—**Richard Lorenz.** Halle, W. Knapp, 1905-6. 3 pts., 8°. (Monographien ueber angewandte elektrochemie, Bde. 20-22.)

Most of the papers comprising these three volumes were originally published in the Zeitschrift fuer anorganische Chemie. The collection has been referred to as a classic in the field of applied electrochemistry.

1574 Die Elektrolyse geschmolzener Salze.—**Richard Lorenz.** graphs. Zeits. f. Elektkrochem., vol. 7, pp. 753-61. July 4, 1901.

See also item 1565.

1575 Die elektrolytische Zersetzungsspannung von geschmolzenem Zinkchlorid.—**Richard Lorenz.** Zeits. f. anorgan. Chem., vol. 12, pp. 272-76. 1896.

Electrolytic decomposition voltage of fused zinc chloride.

—Abstract. Zeits. f. Elektrochem., vol. 3, pp. 135-36. Sept. 20, 1896.

1576 Factory scale experiments with fused electrolytes.—**E. A. Ashcroft.** diagr. Electrochem. & Met. Ind., vol. 4, pp. 143-44, 178-80, 357-58. April, May, Sept., 1906.

"Uses cells provided with means for magnetically rotating the fused bath during electrolysis. For the recovery of zinc from zinc sulphide, the ore is suspended in an electrolyte of fused zinc chloride, and by working at 450° C., the sulphide is resolved into its elements."—J. S. C. I.

—Abstract. Jour. Soc. Chem. Ind., vol. 25, pp. 594-95, 1053. June 30, Nov. 15, 1906.

1577 Gewinnung von Zink mittels Elektrolyse aus Mischungen von Zinksulfid und geschmolzenem Zinkchlorid. Metallurgie, vol. 9, p. 493. Aug. 8, 1912.

Ashcroft's German Patent 245,683, for electrolysis of mixtures of zinc sulphide and fused zinc chloride.

1578 The mechanism of electrolytic transfer.—**J. W. Richards.** Amer. Electrochem. Soc., Trans, vol. 19, pp. 119-25. 1911.

Special reference to the electrolysis of fused salts.

—Abstract. Jour. Inst. Metals, vol. 6, pp. 327-28. 1911.

1579 Method of reducing metals. diagr. Min. & Sci. Press, vol. 113, p. 894. Dec. 16, 1916.

McNitt's patent, 1,197,137.

1580 A new method for the electrolytic winning and refining of metals.—**Edwin M. Chance.** Amer. Electrochem. Soc., vol. 17, pp. 235-38. 1910.

Electrolysis of a fused electrolyte in juxtaposition to a fused anode.

1581 Preparation and electrolysis of pure fused zinc chloride.—**Siegfried Gruenauer.** Zeits. f. anorgan. Chem., vol. 39, pp. 389-476. 1904. (In German.)

—Abstract. Sci. Abst. A, vol. 7, p. 841. Oct., 1904.

—Abstract. Jour. Chem. Soc., vol. 86, pt. II, p. 562. 1904.

—Abstract. Jour. Phys. Chem., vol. 9, p. 176. Feb., 1905.

1582 Refining of zinc from impure zinc dross in an electric furnace.—**Charles A. Weeks.** Met. & Chem. Eng., vol. 9, pp. 364-65. July, 1911.

Part of a longer article on Melting non-ferrous metals in an electric furnace.

—Abstract. Sci. Abst. B, vol. 14, p. 432. Oct., 1911.

—Abstract. Chem. Abst., vol. 5, p. 3199. Oct. 10, 1911.

1583 Sulphide ore treatment (Phoenix process).—**Edgar A. Ashcroft.** diagr. Inst. Min. & Met., Trans., vol. 9, pp. 378-418. 1901.

Discussion of Ashcroft-Swinburne process from the technical and commercial points of view.

—Abstract. diagr. Electrician, vol. 47, pp. 451-53. July 12, 1901.

—Abstract. diagr. Sci. Abst., vol. 4, pp. 973-75. Nov., 1901.

1584 Treatment of complex ores. diagr. Met. & Chem. Eng., vol. 10, pp. 117-19. Feb., 1912.

Discusion of four U. S. Patents (1,011,897-900) issued to E. A. Ashcroft for chlorination treatment and electrolysis of mixed lead-zinc ores or concentrates.

1585 Ueber das Leitvermoegen von geschmolzenem Chlorzink.—**Hermann S. Schultze.** diagr. Zeits. f. anorgan. Chem., vol. 20, pp. 333-39. 1899.

Conductivity of fused zinc chloride.

—Abstract. Zeits. f. Elektrochem., vol. 6, pp. 125-26. Aug. 17, 1899.

1586 Ueber die Elektrolyse von geschmolzenem Chlorzink.—**Hermann S. Schultze.** diagr. Zeits. f. anorgan. Chem., vol. 20, pp. 323-32. 1899.

—Abstract. Electrolysis of fused zinc chloride. Jour. Chem. Soc., vol. 76, pt. II, p. 657. 1899.

1587 The vapor pressures of some concentrated zinc-chloride solutions.—**Alan W. C. Menzies** and **Henrik Boving.** 8th Int. Cong. Appl. Chem., vol. 22, pp. 219-20. 1912.

1588 Verfahren und Vorrichtung zur Gewinnung von Zink und Blei. Zeits. f. Elektrochem., vol. 2, p. 220. Aug. 20, 1895.

Lorenz's German Patent 82,125. Zinciferous lead ores or lead-bearing zinc ores are converted into chlorides, and the fused salts subjected to fractional electrolysis at temperatures between 450° and 700°.

1589 Versuche ueber Gewinnung von Zink im fluessigen Zustandte direkt aus Blende.—**Felix Thomas.** diagr. Metallurgie, vol. 7, pp. 706-10. Nov. 22, 1910.

Researches in the recovery of liquid zinc electrolytically direct from blende. "Blende dissolves in a eutectic mixture of sodium, potassium and manganese silicates to the extent of only .5% at 900°, and a very small yield of zinc is obtained electrolytically. Yields up to 67% are obtained in a closed furnace under pressure, but a large part is in the form of zinc dust. Blende dissolves readily in a mixture of sodium and iron sulphides, which melts at 661°, but the yield of zinc on electrolysis is again small."

—Abstract. Production of zinc direct from Blende. Min. Mag., vol. 4, pp. 61-62. Jan., 1911.

—Abstract. Jour. Soc. Chem. Ind., vol. 29, p. 1457. Dec. 31, 1910.

—Abstract. Met. & Chem. Eng., vol. 9, p. 155. March, 1911.

—Abstract. Chem. Abst., vol. 5, p. 854. March 10, 1911.

—Abstract. Jour. Inst. Metals, vol. 5, p. 298 1911.

—Abstract. Zeits. f. angewandte Chem., vol. 24, pp. 610-11 March 31, 1911.

1590 Versuche zur Begruendung eines gemeinsamen Zink- und Bleigewinnungsverfahrens.— **Richard Lorenz.** Zeits. f. Elektrochem., vol. 2, pp. 318-37. Nov. 5, 1895.

Experiments in the fractional electrolysis of zinc and lead from fused chlorides.

—Abstract. Method of extracting zinc and lead from mixed ores. Jour. Soc. Chem. Ind., vol. 15, pp. 279-80. April 30, 1896.

1591 Weiterer Beitraege zur Kenntnis der Natur des Zinkschwammes.—**F. Foerster** and **O. Guenther.** Zeits. f. Elektrochem., vol. 6, pp. 301-3. Nov. 30, 1899.

The nature of zinc sponge. Contrary to the views expressed in their former paper (item 1595), the formation of spongy zinc can not be attributed to the presence of zinc oxide.

--Abstract. Jour. Soc. Chem. Ind., vol. 19, p. 155. Feb. 28, 1900.

1592 Zink aus Galmei. Zeits. f. Elektrochem., vol. 2, p. 198. Aug. 5, 1895.

Zinc from calamine. Hoepfner's English Patent 11,724 of 1894. Calcium chloride is added to form zinc chloride, which is subjected to electrolysis.

1593 Die Zugutemachung bisher schwer oder nicht verhuettbarer Zinkerze, zinkhaltiger Zwischen- und Abfallprodukte.— **W. Borchers.** Zeits. f. angewandte Chem., vol. 15, pp. 637-42. July 1, 1902.

Treatment of zinc ores and zinciferous waste products hitherto fusible with difficulty or not at all. Chlorination, lixiviation and electrolysis.

--Abstract. Jour. Soc. Chem. Ind., vol. 21, pp. 975-76. July 31, 1902.

—Abstract. Zeits. f. Elektrochem., vol. 8, pp. 707-9. Sept. 11, 1902.

1594 Zugutemachung bisher schwer oder nicht verhuettbarer Zinkerze, zinkhaltiger Zwischen- und Abfallprodukte.— **H. Danneel.** diagr. Zeits. f. Elektrochem., vol. 8, pp. 741-43. Sept. 25, 1902.

Discusses Borscher and Dorsemagen's method of chlorination and electrolysis; Borscher and von Kuegelgen's process of recovering zinc from galvanizers' wastes; Dorsemagen's process for smelting a mixture of calcined soliceous zinc ore and coal in an electric furnace, volatilizing the zinc; and other processes exhibited at the Duesseldorf Exposition of 1902.

—Abstract. Some new electrolytic zinc processes. diagr. Eng. & Min. Jour., vol. 74, p. 544. Oct. 25, 1902.

—Abstract. Reducing zinc from its ores. Electrochem. Ind., vol 1, p. 105. Nov., 1902.

1595 Zur Kenntnis der Elektrolyse von Zinkchloridloesungen, und der Natur des Zinkschwamms.—**F. Foerster** and **O. Guenther.** diagr. Zeits. f. Elektrochem., vol. 5, pp. 16-23. July 7, 1898.

Nature of zinc sponge and methods of preventing its formation; but see item 1591, above.

—Abstract. Jour. Soc. Chem. Ind., vol. 17, pp. 771-72. Aug. 31, 1898.

Dry Chlorination
The Malm and similar processes

1596 The design of a dry chlorination plant.—**Jean McCallum** and **E. J. Bruderlin.** West. Chem. & Met., vol. 6, pp. 206-31. May, 1910.

Includes information on electrolysis of zinc chloride, electrolytic cells, roasting zinc concentrates, costs.

1597 The dry chlorination of complex ores.—**S. A. Ionides.** diagr. Min. & Sci. Press, vol. 112, pp. 781-88. May 27, 1916.

Process for extracting all the metals in an ore, their purification and reduction to metallic form; primarily for complex zinc sulphide ores. Work at the Bunker Hill and Sullivan Plant, Kellogg, Idaho.

1598 Dry chlorination of mixed sulphide ores. diagr. Met. & Chem. Eng., vol. 11, p. 159. March, 1913.

Malm's Patent 1,049,746.

1599 The dry chlorination of sulphide ores.—**Harry J. Wolf.** West. Chem. & Met., vol. 6, pp. 176-91. May, 1910.

Brief review of early processes and description of current practice. The Malm Process and the Western Metals Co.

1600 Importance of the Malm process in the metallurgy of complex ores.—**A. G. Brownlee.** Amer. Min. Cong., Rept., 14, pp. 168-79. 1911.

1601 The Malm dry chlorination process.—**R. L. Herrick.** illus. Mines & Minerals, vol. 30, pp. 370-74. Jan., 1910.

—Abstract. Treatment of complex ores. Jour. Inst. Metals, vol. 3, p. 253. 1910.

—Abstract. Mex. Min. Jour., vol. 10, No. 5, pp. 20-23. May, 1910.

1602 Malm dry chlorine process. Min. Mag., vol. 1, p. 290. Dec., 1909.

Adverse editorial comment.

—Comment.—**E. A. Ashcroft.** Vol. 2, p. 41. Jan., 1910.

"The Electrolysis of pure anhydrous zinc chloride into chlorine and zinc is not a difficult or expensive operation."

—Editorial note. Vol. 2, pp. 92-93. Feb., 1910.
—Comment.—**J. L. Malm.** Vol. 2, pp. 119-20. Feb., 1910.

1603 The Malm process. Eng. & Min. Jour., vol. 101, pp. 679-80. April 15, 1916.

Difficulties in electrolytic decomposition of fused zinc chloride, as attempted at the Bunker Hill & Sullivan plant.

—Reply, by **John L. Malm** and **S. A. Ionides.** Vol. 101, pp. 864-65. May 13, 1916.

1604 The theory of dry chlorination of sulphide ores.—**F. W. Traphagen.** West. Chem. & Met., vol. 5, pp. 89-90. March, 1909.

PATENTS ON ELECTROLYSIS OF FUSED MATERIALS

United States

1605 586,159. Process of treating zinc-sulphide ores.—**Hugo Brewer,** Duisburg, Germany. Filed Sept. 12, 1896. Issued July 13, 1897.

> The process of treating zinciferous sulphate lyes resulting from the lixiviation of chlorinated roasted zinc-sulphide ores, which consists in treating the lye with sodium chloride to saturation or in excess, crystallizing out the sodium sulphate (Glauber salt) formed by refrigeration, treating the lye after removal of the sulphate with calcium chloride, removing the calcium sulphate formed, eliminating from the lye the silver, if any be present, then the iron and successively the other metals if present, as nickel, cobalt and manganese, concentrating the lye by heat, eliminating the sodium chloride formed, treating the resultant lye electrolytically for the extraction of zinc under simultaneous production of chlorine, whereby a final lye is obtained consisting essentially of a solution of calcium chloride and recovering the latter for use in the process.

1606 629,686. Process of extracting zinc from its ores.—**Carl Hoepfner,** Frankfort-on-the-Main, Germany. Filed November 18, 1897. Issued July 25, 1899.

> The process which consists in oxidizing roasting zinciferous sulphide material, converting the resulting sulphurous acid into sulphuric acid, causing the latter to react upon a suitable chloride in the presence of heat and reacting with the hydrochloric acid gas thus formed upon the oxidized material in the presence of a metallic chloride solution, whereby a neutral or slightly basic solution containing zinc in the form of a chloride is obtained, and electrolyzing the latter solution.

—Described in Met. & Chem. Eng., vol. 11, p. 59. Jan., 1913.

1607 642,933. Electrolytic separation of zinc from zinc oxide.—**Oscar J. Steinhart, Julius L. F. Vogel** and **Henry E. Fry,** London, England. Filed April 10, 1899. Issued Feb. 6, 1900.

> The process of separating zinc from zinc oxide, which consists in dissolving zinc oxide in molten zinc chloride mixed with sodium chloride, heating the zinc chloride to a temperature just above the melting-point of zinc, passing an electric current of low voltage through the molten mixture between a layer of molten zinc at the bottom, forming the cathode, and a conductor which dips into the molten mixture of zinc chloride and oxide, and forms the anode, and adding from time to time fresh zinc oxide to the vessel as oxide is decomposed by the current.

1608 679,997. Electrolytic process of obtaining metals from their fused compounds.—**George P. Scholl,** Philadelphia, Pa. Filed Nov. 14, 1898. Issued Aug. 6, 1901.

The process of obtaining metals by electrolysis of their fused compounds, which consists in fusing a bath composed of a mixture of sulphide of the desired metal with a more fusible compound of said metal which is convertible into sulphide by nascent sulphur; subjecting the fused bath to electrolysis by the action of suitable electrodes under a current which will decompose the sulphide only; and continuously renewing the bath by addition of the other constituents in proportion as the metal ingredient is liberated at the cathode.

1609 691,822. Extraction of metals from sulphide ores by treatment with chloride of sulphur and electrolysis.—**James Swinburne** and **Edgar A. Ashcroft,** London, England. Issued Jan. 28, 1902.

The process consists in treating sulphur ores in a fused haloid salt with chloride of sulphur and producing sulphur and chloride; electrolyzing the chloride, thereby producing chlorine and metal, and combining the chlorine with some of the sulphur from the treatment of the sulphide ore using the so-regenerated sulphur chloride for treating more ore.

1610 695,126. Process of extracting metals from sulphide ores.—**James Swinburne** and **Edgar A. Ashcroft,** London, England. Filed Dec. 8, 1899. Issued March 11, 1902.

The process consists in treating sulphide ores, suspended in a bath of fused chloride or chloride with chlorine.

1611 814,810. Metallurgical process.—**Frederick T. Snyder,** Oak Park, Ills. Filed June 23, 1905. Issued March 13, 1906.

The process of treating sulphide ore which consists in dissolving the same in a fused-mineral bath, and subjecting the mixture to the action of an electric current in the presence of carbon at a high temperature, the sulphide being broken down, the metal thereof liberated and carbon bisulphide formed at the same time by the reaction of the sulphur and carbon. 12 claims.

1612 841,103. Process of treating ores.—**Charles E. Baker** and **Arthur W. Burwell,** Cleveland, Ohio. Filed March 1, 1905. Issued Jan. 15, 1907.

The process which consists in reacting with dry sulphur chloride upon dry pulverent sulphide at a suitable temperature, thereby separating sulphur and producing the chloride of the metal or metals of the ore, extracting the metallic chloride, and electro-depositing the metal.

1613 1,011,897. Treatment of complex ores.—**Edgar Arthur Ashcroft,** Sogn, Norway. Filed April 9, 1910. Issued Dec. 19, 1911.

The process of separating metals from zinc sulphide containing other metallic sulphides, which consists in the reaction of zinc chloride with said metallic sulphides in the fused state to precipitate zinc sulphide and dissolve the other metals, pouring off the melt from the residue to separate the liquid melt consisting of zinc chloride having in solution chlorides of the other metals from the solid residual zinc sulphide, thereafter treating the melt to recover

the metals therefrom, performing the separation in two or more stages in cascade, the fused melt passing in one direction and the solid residue being moved in the other direction, washing rapidly the residue with hot water to remove soluble chlorides such as zinc and other metal chlorides therefrom, and adding the solution of chlorides to the melt. 14 claims. Patented also in England, no. 6670 of 1910.

—Described in Met. & Chem. Eng., vol. 10, p. 117-119. Feb., 1912.

1614 1,011,898. Metallurgy of zinc-bearing lead sulphides with or without small admixtures of other metals.—**Edgar Arthur Ashcroft,** Sogn, Norway. Filed April 9, 1910. Issued Dec. 19, 1911.

A process of recovering lead from lead sulphide containing zinc and other sulphides which consists in treating the ore with a fused metallic chloride to dissolve the lead and to form a chloro-sulphide, and separating and electrolyzing said chloro-sulphide separate from the zinc containing minerals. 10 claims. Patented also in England, no. 7329 of 1910.

1615 1,011,899. Metallurgy of metal sulphides.—**Edgar Arthur Ashcroft,** Sogn, Norway. Filed April 9, 1910. Issued Dec. 19, 1911.

A process of treating sulphide ores or products which consists in eliminating the gangue matter, separating the lead and silver present, mixing the remaining product with a fused metal chloride, subjecting the melt to the action of a chlorinating agent, removing the melt to other converters, treating the mixture with chlorine to volatilize the iron and manganese as higher chlorides, passing the chlorides to absorption apparatus wherein they are treated with a solution of sodium hydrate to form sodium chloride and iron and manganese hydrates, separating and electrolyzing the sodium chloride for the production of chlorine and sodium hydrate, utilizing the chlorine for reacting with the mixed sulphides and chlorides in the first converter and the mixed chlorides in the second converters, passing the sodium hydrate to the absorption apparatus to react with the iron and manganese chlorides, and thereafter recovering the other metals present by extracting them by fractional precipitation and electrolysis. 14 claims. Patented also in England, no. 7,444 of 1910 and no. 7,536 of 1910.

1616 1,011,900. Metallurgy of metal sulphides.—**Edgar Arthur Ashcroft,** Sogn, Norway. Filed April 9, 1910. Issued Dec. 19, 1911.

A process of recovering zinc from a mixture containing zinc sulphide which comprises treating the mixture with fused zinc chloride, electrolyzing the melt over a bath of molten lead so as to remove the iron as an alloy, subsequently electrolyzing the melt at low temperature to produce zinc and chloride of sulphur, and reacting the chloride of sulphur with a mixture containing the zinc sulphide to form zinc chloride and sulphur, the zinc chloride being added to the electrolytic bath.

—Described in Met. & Chem. Eng., vol. 10, p. 117-119. Feb., 1912.

1616a 1,049,746. Process of treating metal and mineral bearing materials.—**John L. Malm,** Denver, Colo. Filed Aug. 9, 1909. Issued Jan. 7, 1913.

Consists in subjecting the material to the action of a halogen gas in a receptacle for a sufficient length of time to deliver salts of a part only of the metal or metals in the "ous" condition, and introducing into the receptacle with the gas a cooling agent. 21 claims.

1617 1,066,787. Process of producing zinc from blue powder.—**Warren F. Bleeker,** Cannonsburg, Pa. Filed Jan. 22, 1913. Issued July 8, 1913.

Consists in removing the coating of the particles of the powder and fusing the uncovered zinc particles by placing the blue powder in a receptacle containing a suitable electrolyte, electrolyzing the latter with a direct electric current, and subjecting the receptacle to heat of fusing temperature.

1618 1,254,531. Method or process of smelting zinc.—**Isak Partanen,** Telluride, Colo. Filed Feb. 2, 1916. Issued Jan. 22, 1918.

The method of electrolytically smelting zinc, which consists in chloridizing "blue powder" with chlorine, fusing the zinc chloride and hypochlorite thus produced and then electrolyzing the said zinc chloride and hypochlorite to separate the pure metal.

Great Britain

1619 11,724 of 1894. Improvements in the treatment of calamine or similar minerals or compounds for the extraction of zinc.—**Carl Hoepfner,** Giessen, Germany.

"The calamine or similar mineral is finely powdered and treated with a strong solution of calcium chloride at a high temperature and under pressure. The zinc solution thus obtained is electrolyzed in an apparatus fitted with insoluble anodes from which chlorine is liberated. Only a portion of the zinc is thus precipitated, the remainder being precipitated chemically, preferably by means of hydrate of lime."—J. S. C. I.

1620 25,074 of 1894. Process and apparatus for the production of zinc and lead by electrolysis of the melted chlorides.—**R. O. Lorenz.**

"To effect the working of ores or residues or alloys containing zinc and lead by converting them into chlorides and subjecting them to fractional electrolysis at a temperature of from 450° C to 680° C., with the addition, as may be required, of small quantities of litharge, red lead, peroxide of lead, zinc oxide or other metallic oxides or peroxides or of common salt, potassium chloride, magnesium chloride, sodium fluoride, or other fluxes for preventing frothing and for regulating the process."—J. S. C. I.

—Described in Zeits. f. Elektrochem., vol. 2, pp. 318-27. Nov. 5, 1895.

1621 15,813 of 1895. Improvements in and connected with the production of chlorine and zinc.—**F. M. Lyte,** London.

Blende or mixed blende-galena ores may be roasted and leached with dilute sulphuric acid, and the resulting zinc sulphate solution treated with calcium or sodium chloride. The zinc chloride solution is evaporated to dryness, subjected to distillation and then heated to a temperature slightly above the melting point of zinc, and electrolyzed, a carbon anode and fused zinc cathode being used. See also no. 11,190 of 1897.

1622 28,764 of 1896. Apparatus for use in electrolysis, more especially intended for use in the electrolysis of zinc chloride.—**F. Hurter** and the **United Alkali Co., Ltd.,** Liverpool.

—Described in Jour. Soc. Chem. Ind., vol. 16, p. 1022. Dec. 31, 1897.

1623 10,829 and 10,829 A of 1897. Improvement in the treatment of sulphide ores.—**J. Swinburne,** London.

Treating mixed sulphides with chlorine and depositing the metals by electrolysis of the fused zinc chloride.

—Described in Jour. Soc. Chem. Ind., vol. 17, p. 673. July 30, 1898.

1624 11,190 of 1897. Improvements in the electrolysis of fused zinc chloride.—**F. M. Lyte,** London.

Improvement in English Patent no. 15,813 of 1895. Consists in the complete dehydration of the fused zinc chloride before it is electrolysed. The dehydration is effected by digesting the fused zinc chloride in the presence of metallic zinc, preferably fused.

1625 19,876 of 1898. Electrolytic separation of zinc from zinc oxide.—**O. J. Steinhardt, J. L. F. Vogel** and **H. E. Fry,** London.

"Dissolving zinc oxide in a bath of fused zinc chloride and electrolysing the fused mass with such a current that the zinc is deposited from the oxide, while the chloride remains undecomposed."—E. & M. J.

1626 19,878 of 1898. Zinc chloride making.—**O. J. Steinhart, J. F. L. Vogel** and **H. G. Fry,** London.

"Manufacture of anhydrous zinc chloride and the prevention of its hygroscopic qualities."—E. & M. J.

1627 24,307 of 1898. Electrolytic extraction of zinc and other metals from ores or waste containing them.—**W. Strzoda,** Kattowitz.

The pulverized ore, such as calamine, blende, and the like, or waste containing zinc, is exposed to the action of an electric current directly in an alkaline bath (caustic soda) without any preliminary chemical treatment, whereby the zinc and also the other metals present are at once metallically separated at the cathode.

1628 6,857 of 1901. Treatment of zinc chloride for electrolytic purposes.—**J. Swinburne**, London, and **E. A. Ashcroft**, Milton, England. April 2, 1901.

"Zinc is reduced from the fused chloride by electrolysis, after the zinc chloride has been dehydrated and purified by a preliminary electrolysis."—J. S. C. I.

1629 26,813A of 1905. Electrolysis of fused salts.—E. A. Ashcroft.

"Improvements in the inventor's method of producing metals by the electrolysis of fused salts or ores, consisting in first electrolyzing the ores or salts over a metal and using the alloy so formed as an anode in another cell and so fractionally precipitating the metals of the alloy on the cathode."—E. & M. J.

Germany

1630 245,683. Process for the recovery of zinc by electrolysis from a mixture of zinc sulphide with fused zinc chloride. —**E. A. Ashcroft**, Sogn, Norway. April 12, 1910.

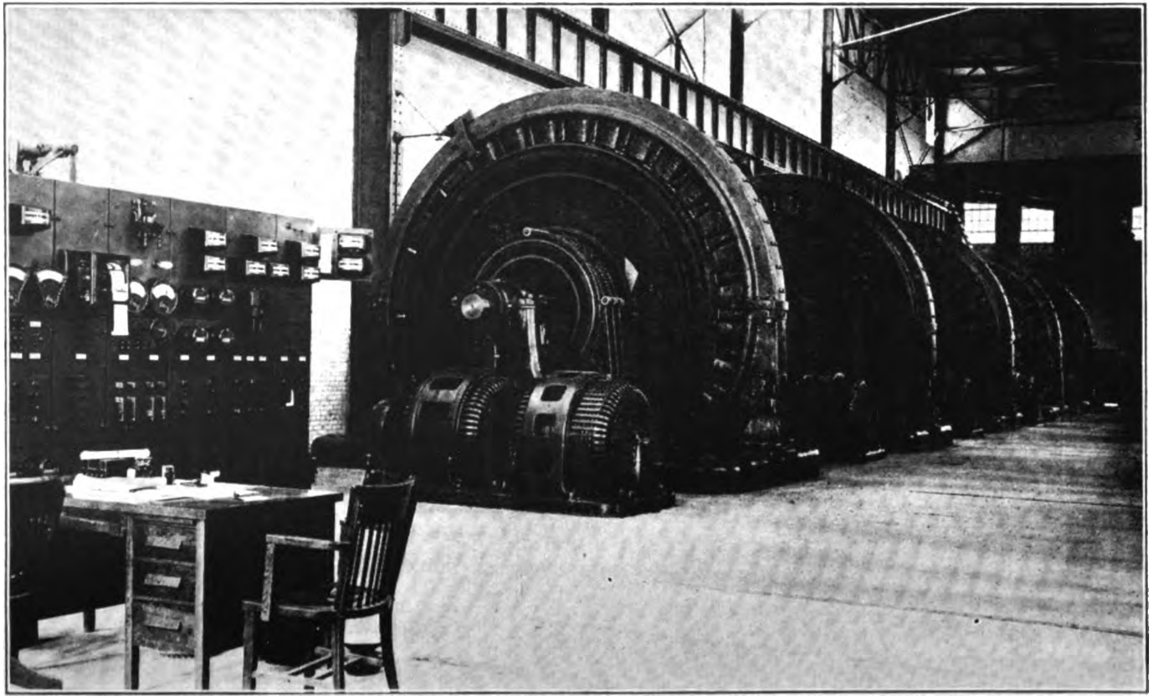
See also item 1577.

—Described in Zeits. f. Elektrochem., vol. 18, p. 792. Sept. 1, 1912.

—Described, with diagr., in Zeits. f. angewandte Chem., vol. 25, pp. 982-83. May 10, 1912.

1631 263,942. Electrolysis of fused zinc salts.—**Fabrik Elektrischer Zuender Ges. m. b. H.** Sept. 25, 1912.

Irregularities due to presence of water or zinc hydroxide in the electrolyte are avoided by the addition of aluminium compounds, e. g., aluminium chloride.



SUBSTATION OF GREAT FALLS ELECTROLYTIC ZINC PLANT, ANACONDA COPPER MINING CO.
Showing five 5800-K. W. rotary converters in operation

ELECTROLYSIS OF AQUEOUS SOLUTIONS

Bibliographies

1632 Electrodeposition of zinc from aqueous solutions.—**E. P. Mathewson.** Canad. Min. Inst., Trans., vol. 20, pp. 135-60. 1917.

Contains an extensive bibliography, chronologically arranged, prepared by the Library Service Bureau of the United Engineering Societies, New York.

—Same. Canad. Min. Inst., Bull. 59, pp. 239-60. March, 1917.

1633 Die englischen elektrochemischen Patente.—**P. Ferchland.** Halle, Wm. Knapp, 1907. 176 pp.

Chronologic list of English patents, 1842-1907, on electrochemistry. No. 29, Monographien ueber angewandte elektrochemie.

1633a Extracts from the technical literature (on steel and zinc). Zeits. f. Elektrochem., vol. 22, pp. 305-14. 1916.

"A review of patents covering electrical processes for the production of steel and zinc."—Chem. Abst. In German.

Electrolysis

1634 Addition agents in the deposition of zinc from zinc sulphate solution.—**O. P. Watts** and **A. C. Shape.** illus. Amer. Electrochem. Soc., Trans., vol. 25, pp. 291-96. 1914.

The effect of the separate addition of 42 different organic substances to a zinc plating solution. Three very promising agents discovered were eikonogen, pyrogallol, and betanaphthol. Gum arabic, benzoic acid, caffeine, formin, and terpinhydrate gave fair results.

—Abstract. Met. & Chem. Eng., vol. 12, p. 339. May, 1914.

1635 Advancement in the metallurgy of zinc.—**M. F. Chase.** Min. Wld., vol. 44, pp. 15-16. Jan. 1, 1916.

Progress during 1915, especially in electrolytic experimentation.

1636 Aerating anode. diagr. Met. & Chem. Eng., vol. 18, p. 485. May 1, 1918.

H. R. Hanley's Patent 1,241,967.

1637 Antimony in zinc electrolytes.—**H. F. Bradley.** Met. & Chem. Eng., vol, 17, p. 275. Sept. 15, 1917.

Materials and method of determination.

1638 Cathodic deposition of zinc in presence of organic bases.—**A. Mazzucchelli.** Atti. R. Accad. Lincei, ser. 5, vol. 23, pt. ii, pp. 503-8. 1914.

Effect of small proportions of salts of quinine, cinchonine, lutidine, aniline, pyridine, gelatin, etc., on the deposition of zinc from a solution of zinc and ammonium sulphates, a pure zinc anode and a brass cathode being used. In Italian.

—Abstract. Jour. Chem. Soc., vol. 108, pt. ii, pp. 670-71. 1915.

—Same abstract. Jour. Soc. Chem, Ind., vol. 34, pp. 1147-48. Nov. 30, 1915.

1639 Chemical reactions taking place at the cathode and anode during the electrolysis of simple salt solutions.—**J. H. Patterson.** Durham Univ. Phil. Soc., Proc., vol. 4, pp. 187-220. 1912.

—Abstract. Jour. Soc. Chem, Ind., vol. 31, p. 1040. Nov. 15, 1912.

1640 The conductivity and ionization of electrolytes in aqueous solutions as conditioned by temperature, dilution and hydrolysis.—**H. C. Jones** and **C. A. Jacobson.** graphs. Amer. Chem. Jour., vol. 40, pp. 355-410. Oct., 1910.

"Investigations to supply data upon the influence of temperature upon dissociation."

1641 Die Darstellung des Zinks auf elektrolytischem Wege.—**Emil Guenther.** Halle, Wm. Knapp, 1904. 245 pp., illus.

Electrolytic zinc recovery. Monographien ueber angewandte Elektrochemie, Band 16.

—Reviewed in Zeits. f. Elektrochem., vol. 11, pp. 55-56. Jan., 20, 1905.

—Reviewed in Zeits. f. angewandte Chem., vol. 18, p. 442. March 17, 1905.

1642 The deposition of zinc from zinc chloride dissolved in acetone.—**H. E. Patten.** graphs. Jour. Phys. Chem., vol. 8, pp. 483-87. Oct., 1904.

Author concludes that this method is not well adapted to produce chemically pure zinc, or to give a thick coat for chemical purposes.

1643 Diaphragm for electrolytic tank. Eng. & Min. Jour., vol. 98, p. 830. Nov. 7, 1914.

N. V. Hybinette advises two perforated lead plates, with loose asbestos between them.

1644 Die direkte elektrolytische Verarbeitung von Erzen und Huettenprodukten.—**W. Borchers.** Berg— u. Huetten. Zeitg., vol. 52, pp. 251-53, 269-71. July 28, Aug 11, 1893.

1645 Les echos de l'electrometallurgie du zinc.—**Rene Sylvany.** Metaux et Alliages, vol. 7, No. 9, pp. 2-4. 1914.

Electrolytic refining and extraction. Siemens-Halske, Cowper-Coles, Hoepfner, Dieffenbach and other methods.

—Abstract: Electrolytic zinc. Jour. Inst. Metals, vol. 12, pp. 317-18. 1914.

1646 Einiges ueber elektrolytische Metallproduktion auf nassen Wege, insbesondere ueber Zinkdarstellung.—**Wilhelm Strzoda.** Chem. Zeitg., vol. 27, pp. 741-43. 1903.

The ore is placed on the cathode, instead of at the anode, in an electrolyte of caustic soda.

—Abstract. Electrolytic production of metals, especially of zinc, in the wet way. Jour. Soc. Chem. Ind., vol. 22, p. 955. Aug. 31, 1903.

1647 Electrodeposition du zinc.—**E. Andreoli.** L'Electricien, vol. 12, pp. 99-102. 1896.

1648 The electrodeposition of metals.—**W. Lash Miller.** Amer. Electrochem. Soc., Trans., vol. 23, pp. 17-23. 1913.

General discussion and review of the development of ideas and theories to present stage.

1649 Electrodeposition of zinc.—**Ralph C. Snowdon.** Amer. Electrochem. Soc., Trans., vol. 11, pp. 121-34. 1907.

An experimental investigation of the conditions affecting the quality of electrolytically deposited zinc. The variables considered were concentration, degree of acidity and alkalinity, reducing agent, current density and temperature.

—Abstract. Electrochem. & Met. Ind., vol. 5, pp. 222-23. June, 1907.

1650 L'electrolyse des solutions de zinc, a Broken Hill. L'electricien, vol. 16, pp. 103-5. 1898.

1651 Electrolysis of alkaline solutions of zinc.—**R. Amberg.** Berichte d. Deutsch. Chem. Gesell., vol. 36, pp. 2489-94. 1903. In German.

—Abstract. Jour. Soc. Chem. Ind., vol. 22, p. 955. Aug. 31, 1903.

1652 The electrolysis of zinc ores.—**Hartwell Conder.** Austral. Min. Stand., vol. 55, p. 307. April 17, 1916.

Discusses leaching and getting the zinc into solution, and its electrolytic deposition.

1653 Electrolysis of zinc solutions. Met. & Chem. Eng., vol. 14, p. 165. Feb. 1. 1916.

Hall's Patent 1,163,911, for addition of $CaCO_3$ to zinc chloride or sulphate solutions.

1654 Electrolytic cell for treating ores. Met. & Chem. Eng., vol. 14, pp. 221-22. Feb. 15. 1916.

Porter's Patent 1,167,594, for a revolving electrolytic diaphragm cell, especially applicable to the recovery of zinc from ores containing considerable iron.

1655 Electrolytic deposition of lead and zinc as affected by the addition of certain organic compounds.—**S. A. Tucker** and **E. G. Thomssen.** Amer. Electrochem. Soc., Trans., vol. 15, pp. 477-83. 1909.

—Abstract. Electrochem. & Met. Ind., vol. 7, p. 273. June, 1909.

1656 The electrolytic deposition of nickel-zinc alloys.—**Eugene P. Schoch** and **Alcan Hirsch.** graph. Jour. Amer. Chem. Soc., vol. 29, pp. 314-24. March, 1907.

"Although zinc has a greater electrolytic solution tension than nickel, a bath which contains much more nickel than zinc yields an alloy containing much more zinc than nickel."

1657 Electrolytic deposition of zinc. Met. & Chem. Eng., vol. 17, pp. 438-39. Oct. 1, 1917.

Perreur-Lloyd's Patents 1,235,723-724.

1657a Electrolytic deposition of zinc.—**H. E. Broughton.** illus., graphs. Chem. & Met. Eng., vol. 20, pp. 155-62. Feb. 15, 1919.

"Description of plant and process of the Ducktown Sulphur, Copper & Iron Co., Isabella, Tenn. Preparation of cell-liquor from fumes collected as a sludge in the acid chambers."

1658 The electrolytic deposition of zinc.—**J. W. Richards.** Amer. Electrochem. Soc., Trans., vol. 25, pp. 281-90. 1914.

Paper read at joint meeting of the New York Sections of the American Electrochemical Society and the American Institute of Mining Engineers.

—Abstract. Met. & Chem. Eng., vol. 11, p. 678. Dec., 1913.

1659 Electrolytic deposition of zinc at the surface of the solution.—**A. A. Titov** and **S. M. Levi.** Jour. Russ. Phys. Chem. Soc., vol. 46, pp. 909-34. 1914.

—Abstract. Jour. Chem. Soc., vol. 108, pt. ii, pp. 312-13. 1915.

—Same Abstract. Jour. Soc. Chem. Ind., vol. 34, p. 802. July 31, 1915.

—Abstract. Chem. Abst., vol. 9, pp. 3031-32. Nov. 20, 1915.

1660 Electrolytic extraction of zinc.—**R. C. V. Whitfield.** Iron & Coal Trades Rev., vol. 82, p. 707. 1911.

—Same. Min. Wld., vol. 34, p. 1128. June 3, 1911.

1661 Electrolytic methods of zinc extraction.—**John B. C. Kershaw.** Elect. Rev., vol. 45, pp. 36-37. 1899.

1662 Electrolytic practice.—**S. E. Bretherton.** Min. & Sci. Press, vol. 113, pp. 793-94. Dec. 2, 1916.

Shows "how the Western mine owner of the so-called complex ores is going to have the advantage over Eastern zinc producers" through transportation costs and cheap power. Describes recent leaching methods.

1663 Electrolytic precipitation of zinc.—**Vilhelm Gruner.** Tidskrift for Kemi, Farmaci og Terapi, vol. 13, pp. 216-20, 232-36. 1916.

"Zinc is electrolytically precipitated in compact form from pure acid solutions if sufficiently stirred. The zinc concentration may be as low as 2%, and the acid as high as 30%." In Norwegian.

—Abstract. Chem. Abst., vol. 10, p. 3033. Dec. 10, 1916.

—Same abstract. Eng. & Min. Jour., vol. 103, p. 353. Feb. 24, 1917.

1663a The electrolytic precipitation of zinc.—**D. McIntosh.** Royal Soc. of Canada, Trans., vol. 2, pt. iii, pp. 113-119. 1917.

"The experimental work was carried out at Trail." 19 pages of photographic illustrations.

—Abstract. Chem. Abst., vol. 13, p. 210. Feb. 10, 1919

1664 Electrolytic process. Met. & Chem. Eng., vol. 18, p. 485. May 1, 1918.

H. R. Hanley's Patent 1,241,966.

1665 Electrolytic process for low grade zinc ores.—**Eduardo Sanna.** Eng. & Min. Jour., vol. 89, p. 1106. May 28, 1910.

The material is dissolved by alkaline salts and electrolyzed. "Obtains compact blocks of zinc by the treatment of electrolytic zinc sponge with pressure and heat combined."

1666 The electrolytic production of zinc. Eng. & Min. Jour., vol. 65, p. 336. March 19, 1898.

Editorial briefly reviewing the Ashcroft, Siemens-Halske, Dieffenbach, and Hoepfner processes.

1667 Electrolytic production of zinc and lead from complex sulphide ore.—**Charles H. Burleigh.** Electrochem. Ind., vol. 2, p. 355-57. Sept., 1904.

"Crushed ore is roasted to produce a maximum of oxide, which is extracted with hot 25% to 40% soda solution." Lead is precipitated with 1.5 to 1.7 volts, and zinc with 2.5 to 7 volts.

See also item 1673.

—Abstract. West. Chem. & Met., vol. 1, pp. 111-12. April, 1905.

1668 Electrolytic recovery of zinc. Min. Wld., vol. 36, p. 120. Jan. 20, 1912.

Chitaro Yoshida, in Japan, dissolves the zinc ore in the electrolyte, and from this liquid the zinc is precipitated by electrolysis. To prevent sponginess, carbon is used instead of lead, in the anode.

1669 The electrolytic recovery of zinc.—**Walter Stoeger.** illus. Min. Jour., vol. 85, pp. 143-44, 170. Jan. 30, Feb. 6, 1909.

Difficulties and causes of failure of many methods. By this method the "sulphide ores are roasted to oxide or a mixture of oxide and sulphate, and leached with sulphuric acid. Calamine is thus leached directly. The liquor is purified and electrolyzed." Gives details and costs.

1670 The electrolytic refining of zinc.—**Otto Steiner.** Elektrochem. Zeits., May, 1908.

Describes the various stages of the operation, and outlines the construction of a commercial plant. In German.

1671 The electrolytic separation of zinc, copper, and iron from arsenic.—**A. K. Balls** and **C. C. McDonnell.** Jour. Ind. & Eng. Chem., vol. 7, pp. 26-29. Jan., 1915.

1672 Electrolytic separation of zinc from its ores. Elektrochem. Zeits., vol. 10, pp. 1-3. 1903.

"Zinc is dissolved by the action of an alkaline solution of alkali hypochlorite, and can then be electrolytically separated from the solution of alkali zincate and chloride." In German.

—Abstract. Jour. Soc. Chem. Ind., vol. 22, p. 704. June 15, 1903.

1673 Electrolytic treatment of zinc sulphides.—**C. H. Burleigh.** Eng. & Min. Jour., vol. 77, pp. 876-77. June 2, 1904.

Mixed lead-zinc ores are electrolyzed in alkaline solution, first for lead and then for zinc. Voltage data is given. A fuller discussion is given above, (item 1667).

—Abstract. Electrochem. & Met. Ind., vol. 2, p. 318. Aug., 1904.

1674 Electrolytic zinc. Min. & Sci. Press, vol. 111, p 950. Dec. 25, 1915.

Editorial.

—Same. Jour. Chem. Met. & Min. Soc. So. Africa, vol. 17, p. 77, Oct., 1916.

1675 Electrolytic zinc. Min. & Sci. Press, vol. 112, p. 432. March 25, 1916.

Editorial.

1676 Electrolytic zinc.—**L. S. Austin.** Min. & Sci. Press, vol. 112, p. 434. March 25, 1916.

The Nahnsen process; and several patents on details of precipitation.

1677 Electrolytic zinc.—**C. A. Hansen.** graphs. Amer. Inst. Min. Eng., Bull. 135, pp. 615-43. March, 1918.

Power characteristics in zinc sulphate electrolysis; current efficiency, corrosion rates, voltage and power requirements; cumulative and non-cumulative impurities; temperature and the stability of the zinc cell. Based on work at Bully Hill, and at the Judge Mining and Smelting Co.

—Abstract. Met. & Chem. Eng., vol. 18, pp. 481-82. May 1, 1918.

—Abstract. Min. Jour., vol. 121, pp. 265, 279-80. May 3, 11, 1918.

1678 Electrolytic zinc.—**Dorsey A. Lyon.** Met. & Chem. Eng., vol. 14, p. 176. Feb. 15, 1916.

Reply to C. A. Hansen (item 1680), in regard to cost of electrolytic plant.

1679 Electrolytic zinc.—**H. A. B. Motherwell.** flow sheet. Min. & Sci. Press, vol. 112, pp. 401-3. March 18, 1916.

Bradley-Williams process, originally worked out on the ore of the Rhodesia Broken Hill mine.

1680 Electrolytic zinc at Bully Hill.—**C. A. Hansen.** illus. Met. & Chem, Eng., vol. 14, pp. 120-22. Feb. 1, 1916.

Correction of statements in article by Lyon, Ralston and Cullen (item 1715). Costs based on Bully Hill, Butte and Superior. See also item 1678, above.

—Abstract. Cost of zinc extraction in America. Min. Mag., vol. 14, pp. 176-77. March, 1916.

1681 Electrolytic zinc dust.—**H. J. Morgan** and **O. C. Ralston.** Amer. Electrochem. Soc., Trans., vol. 30, pp. 229-39. 1916.

Experiments being carried on in an attempt to produce zinc dust from solutions of zinc on a commercial scale, and the substitution of the zinc made in this manner for zinc dust ordinarily used in precipitation of gold and silver in the cyanide process. "The authors have the method of producing dust by electrolyzing the solution of sulphate, the idea being to make a zinc sponge which easily disintegrates."

—Same. Met. & Chem. Eng., vol. 15, pp. 465-68. Oct. 15, 1916.

—Abstract. Min. & Sci. Press, vol. 113, pp. 779-80. Nov. 25, 1916.

—Abstract. Jour. Soc. Chem. Ind., vol. 35, p. 1159. Nov. 30, 1916.

—Abstract. Min. Mag., vol. 15, p. 364. Dec., 1916.

—Abstract. Jour. Franklin Inst., vol. 182, p. 802. Dec., 1916.

—Abstract. Austral. Min. Stand., vol. 57, p. 105, Feb. 15, 1917.

—Abstract. Jour. Chem. Met. & Min. Soc. So. Africa, vol. 17, p. 162. March, 1917.

—Abstract. Sci. Abst. B, vol. 20, p. 229. July, 1917.

1682 Electrolytic zinc extraction by the Hoepfner process.—**E. Guenther.** diagr. Eng. & Min. Jour., vol. 75, p. 750-52. May 16, 1903.

Historical note on the process, with technical details of roasting and leaching, deposition, chlorine recovery, description of electrolytic vats, leaching plant, discussion of costs and yield of products; manufacture of bleaching powder.

—Abstract: Production of zinc. diagr. Electrochem. Ind., vol. 1, pp. 357-58. June, 1903.

—Abstract. diagr. Jour. Soc. Chem. Ind., vol. 22, pp. 749-50. June 30, 1903.

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1684 Electrolytic zinc in Utah.—**C. A. Hansen.** Met. & Chem. Eng., vol. 17, pp. 570-71. Nov. 15, 1917.

Process of the Judge Mining & Smelting Co., as outlined in its annual report.

1685 Electrolytic zinc process. Austral. Min. Stand., vol. 55. p. 264. March 23, 1916.

"Promising results are being obtained in several places in Canada."

1686 Electrolytic zinc process at Great Falls. Min. Jour., vol. 116, pp. 19-20. Jan. 13, 1917.

"Condensed description of the course of treatment" at the refinery of the Anaconda Copper Mining Co.

1687 Electrolytic zinc process in California. Met. & Chem. Eng., vol. 10, p. 47. Jan., 1912.

Brief note descriptive of the Reed process.

1688 Electrolytic zinc; the Reed process.—**E. H. Leslie.** illus. Min. & Sci. Press, vol. 110, pp. 17-21. Jan. 2, 1915.

—Abstract. Electrolytic zinc. Min. Mag., vol. 12, p. 108. Feb., 1915.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 28, pt. II, pp. 321-22. June 25, 1915.

1689 Electrometallurgy of zinc. Eng. & Min. Jour., vol. 100, pp. 325-26. Aug. 21, 1915.

1690 Electrometallurgy of zinc. Min. Jour., vol. 85, p. 460. April 10, 1909.

Presence of iron caused difficulties, and the ore was roasted with coal and limestone, the zinc being burned to oxide. Abstract of article by Campredon in La Metallurgie.

1691 Electrometallurgy of zinc. Min. Jour., vol. 102, p. 791. Aug. 16, 1913.

G. Gallo substitutes zinc fluoride for chloride in preparing solution.

—Same. Eng. & Min. Jour., vol. 96, p. 601. Sept. 27, 1913.

1692 Elektrische Zinkgewinnung. I.—Die Elektrolyse waesseriger Zinkloesung. II.—Die Elektrolyse in Schmelzflusse. —**J. Hess.** diagr. Zeits. f. Elektrochem., vol. 10, pp. 686-93. Sept. 2, 1904.

Electrolysis of aqueous solutions and of fused zinc salts. "A complete review up to 1904." Part III (item 1351) is on electric smelting.

1693 Elektrochemie waesseriger Loesungen.—**Fritz Foerster.** Leipzig, J. A. Barth, 1905. 507 pp. illus. diagr.

The first volume of the "Handbuch der angewandte physikalischen Chemie," edited by Georg Bredig.

—Same; Second edition. 1915.

1694 Elektrochemischen Verfahren der chemischen Gross-Industrie; ihre Prinzipien und ihre Ausfuehrung.—**Jean Billiter.** Halle, Knapp, 1909-11. 2 vols., illus., diagr. 8°.

Electrolytic recovery of zinc from aqueous solutions, vol. 1, pp. 217-44; vol. 2, pp. 484-89.

1695 Elektrolytische Abscheidung von Zink. Metallurgie, vol. 9, p. 490. Aug. 8, 1912.

Electrolytic deposition of zinc from aqueous solution of zinc fluoride, with organic addition agents. J. Matuschek's German Patent 244,930.

1696 Die electrolytische Herstellung von Zinkniederschlaegen. Metallurgie, vol. 1, p. 302. July 22, 1904.

E. Goldberg's German Patent 151,366, for electrolytic deposition of zinc by the addition of nitrogenous substances.

1697 Elektrolytische Zinkgewinnung.—**V. Engelhardt** and **M. Huth.** Metallurgie, vol. 7, pp. 1-5. Jan. 8, 1910.

Review of the electrolytic processes for zinc recovery, showing that "chloride processes have proved unremunerative, while practical difficulties have hitherto stood in the way of a successful sulphate electrolysis, chief of which is the want of a satisfactory anode." Siemens-Halske's manganese dioxide anodes have met this difficulty most satisfactorily.

—Abstract. Met. & Chem. Eng., vol. 8, pp. 152-53. March, 1910.

—Abstract. Jour. Soc. Chem. Ind., vol. 29, p. 159. Feb. 15, 1910.

—Same Abstract. West. Chem. & Met., vol. 6, pp. 113-14. March, 1910.

—Abstract. Jour. Inst. Metals, vol. 3, pp. 266-67. 1910.

—Abstract. Min. Mag., vol. 2, p. 314. April, 1910.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 23, p. 996. May 27, 1910.

1698 Elektrolytische Zinkgewinnung.—**Walther Stoeger.** diagr. Oester. Zeits. f. Berg- u. Huettenw., vol. 57, pp. 1-5. Jan. 2, 1909.

1699 Elektrolytische Zinkgewinnung nach Choate. Zeits. f. Elektrochem., vol. 1, pp. 104-5. June 15, 1894.

U. S. Patent 512,361.

1700 Elektrolytische Zinkgewinnung unter Anwendung unloeslicher Anoden, verbunden mit gleichzeitiger Verwertung des Anodenmaterials.—**J. Rontchewsky.** diagr. Zeits. f. Elektrochem., vol. 7, pp. 21-25, 29-32. July 12, 19, 1900.

Investigation to ascertain whether the insoluble anodes used in the electrolysis of zinc sulphate solutions could be made of further service. For example, a greater expenditure of energy is necessary when the oxygen is allowed to escape than when it is fixed by the material of the anode. Two sets of experiments were made, using lead anodes.

—Abstract. Jour. Soc. Chem. Ind., vol. 19, p. 831. Sept. 29, 1900.

—Abstract, in German. Zeits. f. angewandte Chem., vol. 13, pp. 1188-89. Nov. 20, 1900.

1701 Elektrolytisches Faellen von Zink. Metallurgie, vol. 9, p. 492. Aug. 8, 1912.

1702 Elektrolytisches Verfahren zur Gewinnung von Metallen, wie Kupfer, Zink oder Nickel, aus Material, das die Metalle in teils oxydischer und teils sulfidischer Form enthaelt. Diagr. Metall u. Erz, vol. 12, pp. 301-2. July 22, 1915.

N. V. Hybinette's German Patent 285,652.

1703 Die Elektrometallurgie des Zinkes.—**Erminio Ferraris.** Zeits. f. angewandte Chem., vol. 19, pp. 896-97. May 18, 1906.

Abstract of a paper at the Sixth International Congress of applied Chemistry at Rome.

1704 Elektrometallurgie in waesseriger Loesung: Zink.—**Bernhard Neumann.** Zeits. f. Elektrochem., vol. 15, pp. 456-57. July 1, 1909.

Electrolysis of sulphate solutions.

1705 Extraction and electrolysis of zinc from smelter fumes. diagr. Met. & Chem. Eng., vol. 14, p. 104. 15, 1916.

Best's U. S. Patent 1,154,601. Smelter fumes containing 30% to 35% zinc are roasted at a temperature below that of sulphatic roasting, and leached with weak sulphuric acid, giving a very pure electrolyte.

1706 Formation of floating metallic films by electrolysis.—**F. Mylius** and **O. Fromm.** Ann. der Phys. und. Chem., vol. 51, pp. 593-621. 1894.

"During electrolysis of a concentrated zinc sulphate solution, it was observed that the cathode wire became surrounded by a film of metallic zinc floating upon the surface of the solution, the film increasing gradually to a considerable size... Two necessary conditions are, an impure state of the surface of the solution, and the presence of oxygen in the atmosphere above the solution." In German. See also item 1745.

—Abstract. Jour. Chem. Soc., vol. 66, pt. ii, p. 267. 1894.

1707 Fortschritte der Elektrometallurgie.—**Franz Peters.** Berg- u. Huetten. Zeitg., vol. 61, pp. 526-28. 1902.

1708 Gewinnung von Zink aus blendischen Erzen. diagr. Zeits. f. Elektrochem., vol. 4, p. 99. Aug. 5, 1897.

Roasting, leaching, and electrolysis. English patent 4432 of 1896.

1709 Die Gewinnung von zinc mittels Electrolyse.—**B. Kosmann.** Berg- u. Huetten. Zeitg., vol. 42, pp. 287-90. 1883.

1710 Gewinnung von Zink aus schwer schmelzbaren Zinkerzen. Zeits. f. Elektrochem., vol. 5. pp. 201-2. Oct. 27. 1898.

Jones' English Patent 4296 of 1898.

1711 Grundlagen und jetziger Stand der elektrolytischen Zinkgewinnung.—**Franz Peters.** Berg- u. Huetten. Zeitg., vol. 60, pp. 587-92, 599-604. 1901.

1712 Hall method of zinc electrolysis. Eng. & Min. Jour., vol. 101, p. 263. Feb. 5, 1916.

U. S. Patent 1,163,911; method of maintaining the free ion concentration while electrolyzing zinc sulphate or chloride.

1713 The Hoepfner process for electrolytic production of zinc. diagr. Eng. & Min. Jour., vol. 65, p. 252. Feb. 26, 1898.

Describes the apparatus upon which Hoepfner based his first American patents.

1714 Hydrometallurgy and the electrolytic precipitation of zinc. —**Floyd Dixie James.** Missouri School of Mines, Bulletin, Technical Ser., vol. 4, No. 1. Aug., 1917. 27 pp. illus.

"The purpose of this bulletin is to collect some of the more important information available on this subject, and to give the results of a series of experiments which were made on a number of typical ores." Gives analyses of ores used; discusses roasting of sulphide ores, leaching, purification of solution, and electrodeposition.

1715 Hydrometallurgy of zinc and lead in 1915.—**Dorsey A. Lyon, O. C. Ralston** and **J. F. Cullen.** Met. & Chem. Eng., vol. 14. pp. 30-31. Jan. 1, 1916.

Discusses chiefly electrolytic methods at Trail, Anaconda, Bully Hill, Palo Alto, Silverton, Winnington, Welland, etc.

—Abstract, with comments. Electrolytic refining of zinc. Canad. Min. Jour., vol. 37, pp. 35-36. Jan. 15, 1916.

—Abstract. Jour. Soc. Chem. Ind., vol. 35, p. 182. Feb. 15, 1916.

1716 Industrial extraction of zinc by the electrochemical method. —**I. Escard.** Rev. Electrique, July 30, 1907.

Discusses technical aspects; Luckow, Letrange, Siemens-Halske, Hoepfner, Ashcroft and other processes; electrolytic extraction from pyrites, cinders and complex materials, and electrolysis of fused zinc chloride. In French.

1717 Isherwood process for refractory zinc-lead ores. Met. & Chem. Eng., vol. 12, pp. 351-52. May, 1914.

Isherwood's Patent 1,089,412.

1718 Isherwood's zinc process. Min. Mag., vol. 15, p. 103. Aug. 1916.

Formation of the British Electrolytic Zinc Co. Lists Isherwood's English patents, with specifications of his main patent, 21,584 of 1909.

1719 Latest development in zinc metallurgy. Min. Wld., vol. 43, p. 659. Oct. 23, 1915.

Brief editorial.

1720 Making use of segregation in electrolytic tank. Eng. & Min. Jour., vol. 100, p. 356. Aug. 28, 1916.

Pyne and Green's Patent 1,148,798.

1721 Measurements of the cathodic and anodic polarisation of zinc in the presence of organic basis.—**A. Mazzucchelli.** Atti A. Acad. Lincei, ser. 5, vol. 23, pt. II, pp. 626-33. 1914.

—Abstract. Jour. Chem. Soc., vol. 108, pt. II, p. 671. 1915.

1722 The metallurgy of zinc. Min. Jour., vol. 104, pp. 241-43. March 7, 1914.

Discussion, by G. C. Stone, W. R. Ingalls, J. W. Richards, W. McA. Johnson, E. G. Spilsbury, at joint meeting of American Institute of Mining Engineers and American Electrochemical Society. Chiefly on electrolytic zinc and electrothermic smelting.

1723 A method of electrolytic production of zinc from its ores.—**S. S. Sadtler.** Amer. Electrochem. Soc., Trans., vol. 1, pp. 141-46. 1902.

1724 Neueres ueber Zinkelectrolyse in waessriger Loesung.—**Viktor Engelhardt.** illus., diagr. Metall u. Erz, vol. 10, pp. 60-72. Oct. 22, 1912.

Review of the older work in zinc electrolysis, briefly characterizing the main types of processes which have been tried or suggested. More recent progress in greater detail.

—Abstract. Recent progress in electrolytic process for zinc. Met. & Chem. Eng., vol. 11, pp. 43-44. Jan., 1913.

—Abstract: Zinc electrolysis in aqueous solutions. Min. Jour., vol. 99, p. 1047. Oct. 26, 1912.

—Same abstract. Eng. & Min. Jour., vol. 94, p. 933. Nov. 16, 1912.

1725 Neuerungen in der Elektrometallurgie des Zinks.—**Franz Peters**. diagr. Glueckauf, vol. 51, pp. 584-90, 605-14. June 12, 19, 1915.

Progress in the electrometallurgy of zinc; four pages on electrolysis of aqueous solutions.

1726 Notes sur les depots de zinc par voies electrolytiques en solutions aqueuses de fluosilicate de zinc.—**Robert Goldschmidt**. Rev. d'Electrochem. et d'Electromet., vol. 1, pp. 276-77. 1907.

"As the result of numerous experiments on the electro-deposition of zinc from an electrolyte consisting of a solution of hydrofluosilicic acid of 20° B., exactly neutralized with zinc carbonate, the author found that dense, adherent deposits of a bright grey color, free from the least sponginess, can be obtained by using a rotating cathode and adding some very fine sand to the electrolyte."—J. S. C. I.

1727 Notes upon the hydrometallurgical and electrolytic treatment of zinc ore.—**E. E. Watts.** Met. & Chem. Eng., vol. 16, pp. 645-47. June 1, 1917.

—Abstract. Electrical Wld., vol. 69, p. 1119. June 9, 1917.

—Abstract. Chem. Abst., vol. 11, p. 2168. Aug. 10, 1917.

1728 Nutzbarmachung des auf elektrolytischem Wege erhalten Zinkschwammes. Metallurgie, vol. 7, p. 251. April 22, 1910.

Treatment of electrolytic zinc sponge with sodium nitrate. German patent by E. Sanna.

1729 On the employment of electricity in chemical industries.—**Ferdinand Fischer.** diagr. Dingler's Polytech. Jour., vol. 251, p. 418. 1884.

Discusses the methods of R. P. Herman, Kiliani, Blas and Miest, E. Marchesa, and others.

—Abstract. diagr. Jour. Soc. Chem. Ind., vol. 1, p. 260-61. April 29, 1884.

1730 The Peugeot process of zinc electrolysis. Salt Lake Min. Rev. July 30, 1916. pp. 17-19.

A cyclic process, using sulphuric acid solution. Gives cost data.

1731 Polarization in its relation to the decomposition pressure of electrolytes.—**Oliver P. Watts.** diagr. Amer. Electrochem. Soc., Trans., vol. 19, pp. 91-108. 1911.

Discussion of contemporary theories, with results obtained, and tables illustrating arguments.

1731a Power data for electrolytic zinc.—**G. H. Clevenger** and **F. S. Mulock.** graphs. Chem. & Met. Eng., vol. 20, pp. 156a-b. Feb. 15, 1919.

Two-page insert showing graphically "the relationships between the principal electrical data involved in the production of electrolytic zinc."

1732 Production of zinc coatings electrolytically.—**C. Richter.** Elektrochem. Zeits., vol. 15, pp. 194-98. 1908.

"Lustrous coatings can be obtained electrolytically, at the ordinary temperature, with a current of 1 to 1.5 amperes per sq. dcm., anf 1.135 to 1.8 volts, from a bath containing 140.23 grms. of crystallised zinc sulphate, 42.59 grms. of ammonium sulphate, and 1.274 grams. of sulphuric acid per litre."—J. S. C. I.

1733 A promising electrolytic zinc recovery process. Min. Jour., vol. 84, p. 470. Oct. 10, 1908.

E. Sanna's process.

1734 Refining of zinc. Eng. & Min. Jour., vol. 105, p. 1083. June 15, 1918.

1735 The relative migration velocities of the ions in complex electrolytes: The zinc-ammonia-sulphate plating solution. —**A. Mutscheller.** Met. & Chem. Eng., vol. 13, pp. 439-42. July, 1915.

1736 Stratification of solution as an aid to the purification of electrolytes.—**Francis R. Pyne.** Amer. Electrochem. Soc., Trans., vol. 28, pp. 111-18. 1915.

1737 Some economic factors in the production of electrolytic zinc.—**R. G. Hall.** Amer. Inst. Min. Eng., Trans., vol. 57, pp. 702-19. 1917.

—Same. Amer. Inst. Min. Eng., Bull. 129, pp. 1287-1302. Sept., 1917. Discussion, Bull. 133, pp. 55-57. Jan., 1918.

—Abstract. Met. & Chem. Eng., vol. 17, p. 520. Nov. 1, 1917.

—Abstract. Min. & Sci. Press, vol. 115, pp. 685-88. Nov. 10, 1917.

—Abstract. Chem. Abst., vol. 11, p. 2754. Oct. 20, 1917.

—Abstract. Sci. Abst. B, vol. 20, p. 418. Nov., 1917.

—Abstract of discussion: Effect of impurities in electrolyte Min. & Sci. Press, vol. 116, p. 91. Jan. 19, 1918.

1737a Sui prodcdimenti elettrolitici di estrazione dello zinco e sul loro svilluppo in Italia.—**L. Cambi.** Industria, vol. 32, pp. 736-39. Dec., 1918.

Electrolytic processes of extracting zinc, and their development in Italy.

1738 Sur l'application de l'electricite a la metallurgie du zinc.—**E. Letrange.** Soc. Ingen. Civils de France, Memoires, vol. 34, pp. 602-11. 1881.

1739 Treatment of complex lead-zinc ores.—**Marcus Ruthenburg.** Chem. Trade Jour., vol. 54, p. 56. Jan. 17, 1914.

1740 The treatment of mixed sulphide ores.—**W. R. Ingalls.** Mineral Industry, vol. 7, pp. 741-49. 1898.

Progress in 1898; electrolytic processes of Hoepfner, Ashcroft, Foerster and Guenther, Cowper-Coles and others. Similar reviews of progress and of processes appear in other annual volumes of the Mineral Industry.

1741 Ueber die Destillation und elektrolytische Verarbeitung des Zinkschwammes.—**B. Roesung.** Dingler's Polytech. Jour., vol. 263, pp. 87-94. 1886.

1742 Ueber den Einfluss von Kolloidzusaetzen auf die kathodischen und anodischen Vorgaenge bei der Elektrolyse von Metallsalzloesungen (Blei und Zink).—**R. Marc.** illus. Zeits. f. Elektrochem., vol. 19, pp. 431-44. June 1, 1913.

Effect of colloids as addition agents on the electrical processes at the anode and cathode in electrolysis of metallic salt solutions of lead and zinc. "Effect of gum arabic; gelatine, gum tragacanth, dextrin, starch and albumin on electrolytic deposition from different electrolytes. The results are described in detail and tabulated, but can not be generalized; for whilst colloids act favorably by diminishing the size of grain of the deposit, they frequently have an injurious effect on the coherence and strength of the deposit. In general, colloids appeared to cause an increased liberation of Hydrogen at the cathode, but their effect on anodic reactions varied according to the nature of the electrolyte and of the colloid."—J. S. C. I.

1743 Ueber die Elektrolyse alkalischer Zinkloesungen.—**Richard Amberg.** Berichte der Deutsch. Chem. Gesell., vol. 36, pp. 2489-94. 1903.

"Zinc can be deposited in a coherent form from its solution in potassium hydroxide without the addition of another electrolyte."

—Abstract. Electrolysis of alkaline solutions of zinc. Jour. Soc. Chem. Ind., vol 22, p. 955. Aug. 31, 1903.

1744 Ueber die elektrochemische Bereitung von Zinkoxydkali-Loesung.—**Paul Schoop.** diagr. Zeits. f. Elektrochem., vol. 1, pp. 205-8, 247-49. Sept. 15, Oct. 1, 1894.

Electrochemical preparation of zinc-potassium oxide.

1745 Ueber die elektrolytische Bildung von Zinkblaettern auf Oberflaechen.—**H. Freundlich** and **W. Novikow.** Zeits. f. Elektrochem., vol. 16, pp. 394-400. June 1, 1910.

Electrolytic formation of zinc flakes on surfaces. "If commercial zinc sulphate is electrolyzed in a flat dish, with a platinum point just at the surface of the liquid as the cathode, the zinc separates as a thin lustrous film around the cathode. Oxygen is necessary for the occurence of the phenomenon... and there must also be on the surface of the electrolyte a film of some insoluble liquid."—J. S. C. I. See also item 1706.

—Abstract. Zeits. f. angewandte Chem., vol. 23, p. 1529. Aug. 12, 1910.

—Abstract. Jour. Soc. Chem. Ind., vol. 29, p. 762. June 30, 1910.

—Abstract. Chem. Abst., vol. 4, pp. 2063-64. Aug. 20, 1910.

—Abstract. Sci. Abst. A, vol. 13, p. 400. August, 1910.

1746 Ueber Zinkelektrolyse mit waesserigen Elektrolyten.—**Ernst Hase.** illus. Berg- u. Huetten. Zeitg., vol. 54, pp. 431-35, 439-43. Dec. 13, 20, 1895.

1747 Die Verarbeitung zinkhaltiger Bleiglanze.—**W. Borchers.** Zeits. f. Elektrochem., vol. 2, pp. 277-78. Oct. 5, 1895.

The reduction of zinc-bearing lead ores, by (1) Oxydizing roast at low temperature; (2) Conversion of the zinc into sulphate by treating with sulphuric acid; (3) Lixiviation to extract the sulphate; (4) Electrolysis for metallic zinc; (5) Smelting residue for crude lead; (6) Desilverization.

—Abstract. Jour. Soc. Chem. Ind., vol. 15, p. 362. May 30, 1896.

—Criticism.—**Robert C. Schuepphaus,** and reply by W. Borchers. Zeits. f. Elektrochem., vol. 2, pp. 347-48. Nov. 20, 1895.

Borcher's process was unsuccessful in Colorado, and that of Lungwitz was considered more promising.

—Abstract of the criticism. Jour. Soc. Chem. Ind., vol. 15, p. 280. April 30, 1896.

—Same abstract. Eng. & Min. Jour., vol. 62, p. 75. July 25, 1896.

1748 Die Verarbeitung der Erze vermittelst Elektrizitaet; Zink.—**Martin Kiliani.** Berg- u. Huetten. Zeitg., vol. 42, pp 250-52. 1883.

1749 Verfahren zur elektrolytischen Gewinnung von Kupfer und Zink aus Erzen. Metallurgie, vol. 1, pp. 439-41. Oct. 22, 1904.

Laszczynski's U. S. Patent 757,817. Prevents anodic oxidation by use of insoluble anodes tightly wrapped in a porous or permeable envelope of fabric or other suitable material.

1750 Verfahren zur elektrolytischen Zinkgewinnung Zeits. f. Elektrochem., vol. 2, pp. 198-99. Aug. 5, 1895.

Lindemann's process for electrolysis with addition of zinc sulphide.

1751 Verfahren zum Haltbarmachen von elektrolytisch gewonnenem Zinkschwamm. Metall u. Erz, vol. 12, pp. 104-5. March 8, 1915.

German Patent 282,234, for making zinc sponge stable.

1752 Versuche zur Begruendung eines gemeinsamen elektrolytischen Zink- und Bleigewinnungsverfahrens.—**Richard Lorenz.** diagr. Zeits. f. anorgan. Chem., vol. 10, pp. 78-116. 1895.

Simultaneous electrolysis of zinc and lead.

1753 Versuche zur Herstellung von reinen Zink.—**F. Mylius** and **O. Fromm.** diagr. Berichte der Deutsch. Chem. Gesell., vol. 28, pp. 1563-75. 1895.

Describes various dry and electrolytic methods for the purification of "commercially pure" zinc.

—Same. Zeits. f. anorgan. Chem., vol. 9, pp. 144-77. 1895.

—Abstract. Zeits. f. Elektrochem., vol. 2, pp. 220-24. Aug. 20, 1895.

—Abstract: Preparation of pure zinc. Jour. Soc. Chem. Ind., vol. 14, p. 867. Oct. 31, 1895.

1754 Verzinkerei. Metallurgie, vol. 1, p. 54. Feb. 8, 1904.

Addition of a double sulphate of aluminum and magnesium to a bath of zinc sulphate to promote electrodeposition of zinc.

1755 Von der elektrochemischen Metallindustrie Deutschlands.—**H. Danneel.** Zeits. f. Elektrochem., vol. 8, pp. 137-42. March 6, 1902.

Effect of impurities, especially iron.

—Abstract. Electrical Wld., vol. 39, p. 608. April 5, 1902.

—Same abstract. Jour. Franklin Inst., vol. 154, pp. 31-32. July, 1902.

1756 Vorbereitung zinkischen Rohmaterials zur Elektrolyse nach Nahnsen. Zeits. f. Elektrochem., vol. 1, pp. 301-2. Nov. 1, 1894.

Preparing zinc ores for electrolysis. "Ores which, like the upper Silesian ores, contain electro-positive metals such as calcium and magnesium, yield a leach liquor ill suited to electrolysis." The noxious material is eliminated by roasting and leaching.

1757 Wet and electrolytic methods of treatment of zinc ores.—**E. E. Watts.** Met. & Chem. Eng., vol. 16, pp. 645-47. June 1, 1917.

Results of investigations carried out on a dense sulphide ore from the Sullivan Mine, Kimberly, B.C., and on various ores at Welland, Ont. Paper before American Chemical Society.

—Abstract. Sci. Abst. B, vol. 20, pp. 273-74. Aug., 1917.

1757a Lo zinco elettrolitico. Rassegna Mineraria, vol. 24, pp. 97-100. June, 1918.

1758 Zinkoxyd durch Elektrolyse von Zink in Natriumsulfatloesung. Metallurgie, vol. 1, p. 371. Sept. 8, 1904.

Production of zinc oxide by electrolysis of zinc in a solution of sodium sulphate.

1759 Zur elektrolytischen Zinkgewinnung.—**B. Neumann.** Chem.-Zeitg., vol. 20, pp. 36-38. 1896.

Discusses many of the difficulties in preparing suitable electrolytes, and the processes which have aimed to solve the difficulties.

—Abstract. Electrolytic zinc extraction. Jour. Soc. Chem. Ind., vol. 15. pp. 280-81. Apr. 30. 1896.

—Same abstract. Eng. & Min. Jour., vol. 62, p. 52. July 18, 1896.

1760 Zur Elektrometallurgie des Zinks.—**Franz Peters.** Glueckauf, vol. 41, pp. 1496-1502. 1905.

The Anaconda-Great Falls Process

See also items 1813-17, 1819, 1822, 1824, 1893-94, 1905-10, 1913, 1913a.

1761 Anaconda begins production of electrolytic zinc. Eng. & Min. Jour., vol. 102, p. 587. Sept. 30, 1916.

1762 Details of the electrolytic zinc process. Diagr. Met. & Chem. Eng., vol. 18, pp. 549-50. May 15, 1918.

Laist & Elton's Patents 1,255,433-439.

1763 Electrolytic zinc.—**W. R. Ingalls.** Amer. Electrochem. Soc., Trans., vol. 29, pp. 347-56. 1916.

Conditions governing production of electrolytic zinc; chemistry of process; description of Anaconda process; commercial and technical limitations.

—Same. Eng. & Min. Jour., vol. 101, pp. 425-28. March 4, 1916.

—Same. Min. Jour., vol. 112, pp. 198-200. March 25, 1916.

—Same. Min. & Sci. Press, vol. 112, pp. 439-42. March 25, 1916.

—Same (description of Anaconda plant slightly condensed). Met. & Chem. Eng., vol. 14, pp. 264-65. March 1, 1916.

—Abstract. Electrolytic zinc. Min. Mag., vol. 14, p. 234. April, 1916.

1764 Electro-deposition of zinc from aqueous solutions.—**E. P. Mathewson.** Canad. Min. Inst., Trans., vol. 20, pp. 135-60. 1917.

The Anaconda methods are outlined in the first two and one-half pages. The remainder of the article comprises a bibliography.

—Same. Canad. Min. Inst., Bull. 59, pp. 239-60. March, 1917.

—Abstract. Canad. Min. Jour., vol. 38, p. 125. March 15, 1917.

—Abstract. Min. Mag., vol. 16, p. 220. April, 1917.

—Abstract. Min. & Sci. Press, vol. 114, p. 669. May 12, 1917.

1765 Electrolytic zinc. Min. & Sci. Press, vol. 111, p. 803. Nov. 27, 1915.

1766 Electrolytic zinc production.—**W. R. Ingalls.** Mineral Industry, vol. 27, pp. 743-50. 1915.

Chemistry and details of Laist's process at Anaconda; difficulties of electrolysis.

The Ashcroft Process

See also Ashcroft's work on the electrolysis of fused materials.

1767 The Ashcroft process for the treatment of mixed lead and zinc sulphide ores.—**W. R. Ingalls.** Eng. & Min. Jour., vol. 66, pp. 488-90. Oct. 22, 1898.

Deposition from sulphate solution. "An account, estimate, and criticism of the process and its practical failure in Australia."

—Abstract. Jour. Soc. Chem. Ind., vol. 17, p. 1153. Dec. 31, 1898.

1768 The Ashcroft zinc extraction process at Cockle Creek. Electrician, vol. 41, p. 419. July 22, 1898.

Deposition from chloride solution. Description of the method and of the plant, which was put in operation in March, 1897, and during a run of four months produced 150 tons of zinc.

1769 The treatment of Broken Hill sulphide ores by wet extraction processes, and the electrolytic deposition of zinc. —**Edgar A. Ashcroft.** Inst. Min. & Met., Trans., vol. 6, pp. 282-337. 1897-98.

Detailed description of author's process, with costs.

—Abstract. Electrician, vol. 41, pp. 554-58. Aug. 19, 1898.

—Abstract in German. Zeits. f. Elektrochem., vol. 5, pp. 182-87. Oct. 13, 1898.

1770 Verarbeitung zinkischer Erze. diagr. Zeits. f. Elektrochem., vol. 2, pp. 376-77. Dec. 5, 1895.

U. S. Patent 546,873. Addition of ferric chloride and use of an iron anode.

Cowper-Coles' Process

1771 Cowper-Coles' electrolytic method for the extraction of zinc from refractory ores. Elect. Rev., vol. 43, pp. 265-67. Aug. 19, 1898.

1772 Cowper-Coles process for the treatment of refractory ores. Elect. Rev., vol. 43, pp. 788-89. 1898.

1773 The electro-deposition of zinc.—**Sherard Cowper-Coles.** illus., diagr. Jour. Soc. Chem. Ind., vol. 15, pp. 414-17. June 30, 1896.

Deposition of zinc on iron, from a solution of $ZnSO_4$, $FeSO_4$, and water, using a lead anode.

—Abstract, in German. Zeits. f. Elektrochem., vol. 3, pp. 133-34. Sept. 20, 1896.

1774 Electrolytic treatment of complex sulphide ores.—**Sherard-Cowper-Coles.** Electrician, vol. 44, pp. 81-83, 111-13, 157-59. Nov. 10, 17, 24, 1899.

1775 Elektrolytische Verzinkung.—**Sherard Cowper-Coles.** Translated into German by Emil Abel. Halle, Wm. Knapp. 1905. 37 pp., illus. 8°.

Monographien ueber angewandte Elektrochemie, Bd. 18.

1776 Elektrolytische Zinkfaellung unter Druck. Zeits. f. Elektrochem., vol. 6, pp. 435-36. Feb. 15, 1900.

Electrolysis under a pressure of 70 atmospheres.

1777 Some notes on the electrodeposition of zinc under pressure. —**Sherard Cowper-Coles.** Electrician, vol. 44, p. 183. Dec. 1, 1899.

1778 Some recent investigations in connection with the electrodeposition of zinc.—**Sherard Cowper-Coles.** illus. Electrician, vol. 41, pp. 382-83. July 15, 1898.

Results of experiments on the formation of spongy zinc. "A special cell was used with a revolving aluminum cathode; the zinc was deposited from a sulphate solution, various gases being formed over the cathode during deposition. The best deposits were obtained when coal gas and carbon dioxide were used."—J. S. C. I.

1779 Zinkgewinnung aus sulfidischen Zink-erzen. Zeits. f. Elektrochem., vol. 5, pp. 379-80. Feb. 16, 1899.

English Patent 5943 of 1898; electrolytic recovery of zinc from Broken Hill sulphide ores.

French's Process

1780 Electrolytic recovery of zinc and manganese. Met. & Chem. Eng., vol. 11, p. 293. May, 1913.

U. S. Patents 1,055,157-158.

1781 The electrolytic refinery at Trail, B. C.—**John F. Miller.** Illus. Min. Wld., vol. 39, pp. 57-59. July 12, 1913.

1782 Electrolytic refining at Trail.—**T. A. Rickard.** illus., diagr., map. Min. & Sci. Press, vol. 113, pp. 903-7, 939-41. Dec. 23, 30, 1916.

Zinc roasting, leaching and electrolytic methods described in detail.

—Comment and corrections.—**Thomas French** and **E. H. Hamilton.** Vol. 114, p. 77. Jan. 20, 1917.

1783 Electrolytic zinc at Trail. Min. & Sci. Press, vol. 113, pp. 933-34. Dec. 30, 1916.

Review of events in the development of electrolytic zinc process in British Columbia. Outline of French's process.

—Abstract. Min. Mag., vol. 16, pp. 107-8. Feb., 1917.

1784 Electrolytic zinc extraction at Trail, B. C.—**E. H. Hamilton.** Amer. Electrochem. Soc., Trans., vol. 32, pp. 317-19. 1917.

Details of roasting, leaching, purification of electrolyte, construction of electrolytic tanks, and the process of electrolysis.

1785 The French electrolytic process. Min. Wld., vol. 45, p. 450. Sept. 9, 1916.

1786 The "French" process. Canad. Min. Inst., Bull. 40, pp. 584-86. Aug., 1915.

Excerpt from Nelson Daily News, July 8, 1915.

—Same. French process for electrolytic zinc. Met. & Chem. Eng., vol. 13, pp. 888-89. Dec. 1, 1915.

—Abstract. Electrolytic zinc. Min. Mag., vol. 13, pp. 167-68. Sept., 1915.

1787 The French zinc process. Met. & Chem. Eng., vol. 10, p. 112. Feb., 1912.

1788 The French zinc process. Min. & Sci. Press, vol. 111, p. 404. Sept. 11, 1915.

1789 French's zinc process. Min. Mag., vol. 7, p. 223. Sept., 1912.

Brief note: "Novelty and commercial value are not apparent."

1790 The French zinc process.—**W. F. Robertson.** Mex. Min. Jour., vol. 15, No. 6, pp. 38-39. Dec., 1912.

1791 The French zinc process at the Standard property, Silverton, B. C. Min. Wld., vol. 44, p. 741. April 15, 1916.

Zinc is dissolved from the roasted ore by means of "bisulphate of soda, to which a little manganesite has been added. The zinc is then precipitated electrolytically."

1792 French's process for reduction of zinc-lead ores. Canad. Min. Jour., vol. 36, p. 610. Oct. 1, 1915.

1793 French's zinc treatment process. Canad. Min. Jour., vol. 38, p. 124. March 15, 1917.

Excerpt from Victoria, B. C., Daily Times.

1794 The future of electrolytic zinc.—**Thomas French.** Amer. Electrochem. Soc., Trans., vol. 32, pp. 321-28. 1917.

A discussion of the comparative merits of the retort and electrolytic processes, with details of costs. The conditions of satisfactory roasting, leaching and depositing pure zinc are considered.

—Same. Met. & Chem. Eng., vol. 17, pp. 647-49. Dec. 1, 1917.

—Abstract. Min. & Sci. Press, vol. 116, p. 159. Feb. 2, 1918.

1795 Some of the difficulties of the electrolytic process.—**Thomas French.** Met. & Chem. Eng., vol. 17, p. 37. July 1, 1917.

1796 Some problems in the production of electrolytic zinc.—**E. H. Hamilton.** Eng. & Min. Jour., vol. 103, p. 270. Feb. 10, 1917.

Brief abstract from annual report of the Consolidated Mining & Smelting Co. of Canada.

Gillies Process

See also items 1912, 1981.

1797 Electrolytic treatment of complex zinciferous ores.—**P. M. Gillies.** Austral. Min. Stand., vol. 58, pp. 199, 213-14. Sept. 27, Oct. 4, 1917.

The Gillies process, at Broken Hill, consists of "coarse crushing the ore; partial roasting, and fuming off of zinc and lead, etc.; dissolving the zinc from this 'fume'; purifying the solutions; electrolysis; and smelting the residues." Detailed description, and comparison with other processes.

—Abstract, in German. Metall u. Erz, vol. 15, p. 169. May 22, 1918.

1798 Electrolytic zinc; success of the Gillies process. Austral. Min. Stand., vol. 55, p. 130. Feb. 10, 1916.

1798a Treatment of zinciferous ores. Chem. & Met. Eng., vol. 20, pp. 544-45. May 15, 1919.

Australian Patent 6,456 of 1918, by J. H. and P.McP. Gillies. Fume dust from the baghouse, treated with sulphuric acid and barium sulphide, is electrolyzed, using zinc plates as cathodes. Gum arabic insures even deposition of zinc.

1799 Verfahren zur Behandlung von zinkhaltigen Erzen und Huettenerzeugnissen. Metallurgie, vol. 7, p. 285. May 8, 1910.

J. H. Gillies' German Patent.

The Siemens-Halske Process

1800 The electrolytic precipitation of metallic zinc by electrolysis of sulphate of zinc solutions.—**Siemens** and **Halske.** Min. Jour., vol. 82, p. 515. Oct. 26, 1907.

Translated from the Revue Chimique.

1801 Elektrolytische Gewinnung von Zink aus Kiessabbraenden. Metallurgie, vol. 8, pp. 477-78. Aug. 8, 1911.

German Patent 233,252, for electrolytic recovery of zinc from pyritic residues.

1802 Elektrolytische Gewinnung von Zink aus Sulfatloesungen. Metallurgie, vol. 2, 545-46. Nov. 22, 1905.

German Patent 162,785; recommends stronger current at the anode than at the cathode.

1803 Enteisenung der fuer die elektrolytische Zinkgewinnung bestimmten Zinksulfatloesungen mittels Superoxyden und Zinkoxyd. Metallurgie, vol. 6, p. 695. Nov. 8, 1909.

German Patent 213,004; addition of manganese peroxide for eliminating iron from zinc sulphate solutions intended for the electrolytic recovery of zinc.

—Abstract. Electrolytic recovery of zinc. Min. Jour., vol. 87, p. 304. Nov. 20, 1909.

1804 Verfahren zur elektrolytischen Gewinnung von Zink aus Sulfatloesungen. Zeits. f. Elektrochem., vol. 12, p. 74. Jan. 26, 1906.

"By the use of a very small anode, the tendency toward formation of spongy zinc can be overcome."

—Abstract: Electrolytic deposition of zinc. Eng. & Min. Jour., vol. 81, p. 424. March 3, 1906.

1805 Zinc recovery from solution. Eng. & Min. Jour., vol. 78, p. 920. Dec. 8, 1904.

The current density at the anode is made very much greater than at the cathode, in order to prevent the spongy formation and the redissolving of the zinc formed. English patent 16,396 of 1904.

1806 Zink. Zeits. f. Elektrochem. Vol. 2, p. 646. June 5, 1896.

Aluminium sulphate is used as electrolyte. English Patent 1575 of 1896.

1807 Zink. Zeits. f. Elekktrochem. Vol. 2, p. 257-58. Nov. 20, 1895.

Process by which compressed air is introduced into the electrolyte. English Patent 13,434 of 1895.

Tainton and Pring's Investigations

See also items 1887, 1898, 1903, 1904, 1976.

1808 Electrodeposition and refining of zinc. Met. & Chem. Eng., vol. 11, p. 346. June, 1913.

U. S. Patent 1,059,233. Method of electrolyzing a strongly acid solution of a zinc salt with a current of high density.

1809 Electrodeposition of zinc. Eng. & Min. Jour., vol. 96, p. 502. Sept. 13, 1913.

U. S. Patent 1,059,233. Use of a colloidal addition agent.

1810 The electro-deposition of zinc at high current densities.—**J. N. Pring and U. C. Tainton.** illus., diagr. Jour. Chem. Soc., vol. 105, pp. 710-24. 1914.

"A systematic investigation of the different factors which regulate and influence the deposition of zinc by electrolysis."

—Abstract. Jour. Inst. Metals, vol. 12, p. 323. 1914.
—Abseract. Chem. Abst., vol. 8, p. 2115. June 20, 1914.

1811 Electrolytic zinc. Met. & Chem. Eng., vol. 17, pp. 40-41. July 1, 1917.

U. S. Patent 1,210,017.

1812 The influence of the physical condition of metals on cathodic overvoltage.—**J. N. Pring** and **J. R. Curzon.** Faraday Soc., Trans., vol. 7, pp. 237-45. June, 1912.
—Abstract. Chem. Abst., vol. 6, p. 2715. Oct. 10, 1912.

Electrolytic Zinc Plants

A list of electrolytic plants, with the capacity of each, may be found in the recent volumes of the U. S. Geological Survey's annual publication, "Mineral Resources of the United States," in the annual volumes of "The Mineral Industry," the "Engineering and Mining Journal," and elsewhere. See also page 353.

1813 Anaconda Company's zinc refinery. Salt Lake Min. Rev., Oct. 30, 1916. pp. 22-23.

1814 Anaconda produces spelter. Eng. & Min. Jour., vol. 100, p. 814. Nov. 13, 1915.

1815 Anaconda to build big zinc reduction plant. Min. Wld., vol. 43, pp. 1013-14. Dec. 25, 1915.

Great Falls plant.

1816 Anaconda's electrolytic zinc plant. Met. & Chem. Eng., vol. 14, p. 132. Feb. 1, 1916.

1817 Anaconda's electrolytic zinc plant. Eng. & Min. Jour., vol. 102, pp. 1103-5. Dec. 23, 1916.

Illustrations only.

1818 Electrolytic zinc plant. Min. Wld., vol. 45, p. 412. Sept. 2, 1916.

Judge Mining & Smelting Co., Park City, Utah.

1819 Great Falls electrolytic zinc plant. Met. & Chem. Eng., vol. 14, p. 177. Feb. 15, 1916.

1820 The Judge zinc plant. Eng. & Min Jour., vol 103, p. 832. May 12, 1917.

Abstract of report of Judge Mining & Smelting Co.

1821 Metallurgical improvements in British Columbia.—**E. Jacobs.** Canad. Min. Jour., vol. 37, pp. 251-52. May 15, 1916.

Additions and improvements to plants at Trail, at Britannia Mining & Smelting Co., Britannia Beach, and at Granby Consolidated, Anyox.

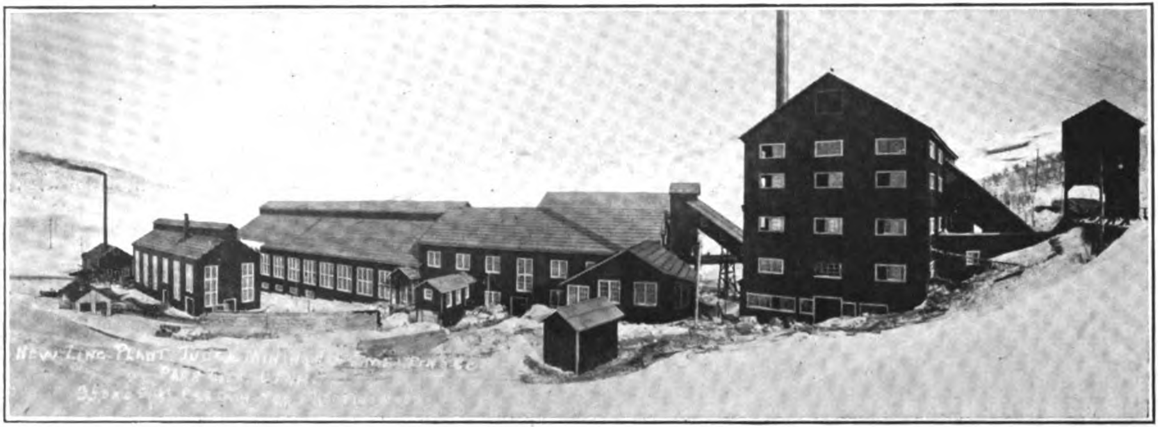
1822 New experimental zinc plant of Anaconda Co. Eng. & Min. Jour., vol. 100, p. 941. Dec. 4, 1915.

1823 Refining metals at Trail, B. C. Canad. Min. Jour., vol. 37, p. 314. July 1, 1916.

Comments of Prof. F. A. Thompson of Washington State College, reprinted from Trail News of June 9, 1916.

1824 Washoe reduction works, Anaconda.—**L. S. Austin.** Illus., diagr. Min. & Sci. Press, vol. 112, pp. 195-202, 304-9, 547-55. Feb. 5, 26, April 15, 1916.

Part 1, Roaster plant; part 2, The coarse concentrator and flotation plant; part 3, the electrolytic zinc plant, the leaching plant.



JUDGE MINING AND SMELTING COMPANY
Electrolytic Zinc Plant, Park City, Utah

PATENTS ON ELECTROLYSIS OF AQUEOUS SOLUTIONS

United States

1825 415,576. Electrolysis of zinc, copper, etc. **Werner Siemens**, Berlin, assignor to Siemens-Halske. Issued Nov. 19, 1889.

> "Lixiviates the ore with solution of ferric sulphate, chloride or cyanide, which dissolves the metal and is reduced to the ferrous form. Electrolyzes the resulting solution at the cathode, depositing the non-ferrous metal; then reoxidizing the residual solution at the anode to the ferric form..."

—Abstract. Met. & Chem. Eng., vol. 9, pp. 429-430. Aug., 1911.

1826 415,738. Electrolysis of copper, zinc or tin.—**Hermann A. Seegall**, Berlin. Issued Nov. 26, 1889.

> "Lixiviates the ores first with ferric chloride and then with a solution capable of dissolving the residual cuprous chloride in the ore. The second solution, plus ferric chloride, may be electrolized in an open cell, or at the cathode in a diaphragm cell with ferrous chloride in the anode compartment.."

—Described in Met. & Chem. Eng., vol. 9, p. 430. Aug., 1911.

1827 459,556. Process of electrolytically obtaining zinc.—**Alexander Watt**, London, England. Filed March 22, 1889. Issued September 15, 1891.

> The improvement in the art of preparing zinc-bearing ores for electrolysis, which consists in digesting the powdered ore in acetic acid and sulphuric acid, at first separately and afterward jointly, to form an electrolyte.

1827a 460,354. Apparatus for electrolytically separating metals from their ores.—**Werner von Siemens**, Berlin, German, assignor to Siemens & Halske. Filed June 30, 1890. Issued Sept. 29, 1891.

> In an electrolytical cell, the combination of a revolving cathode, a trough-shaped anode situated below said cathode, in the trough of which the cathode revolves, a screen permitting the passage of the electrolyte and of electricity and capable of preventing the passage of vibrations of the electrolyte situated between the said cathode and anode, and means for supplying the electrolyte above the screen and for withdrawing the oxidized liquid from the bottom of the trough of the anode. Patented also in Germany, No. 48,959; in Spain, No. 9,318 of 1889; in Italy, No. 25,017; and in Austria-Hungary, Nos. 2,784 and 2,772 of 1890.

1828 473,186. Method of producing metallic zinc.—**Parker C. Choate**, Brooklyn, N. Y. Filed Jan. 5, 1891. Issued April 19, 1892.

> The process of producing metallic zinc from its ores, which consists in separating the zinc and the equally volatile and more volatile constituents from the less volatile constituents of the ore

by the use of heat and a reducing agent, then volatilizing and oxidizing the reduced metal, thereby obtaining a condensed oxidized fume, subjecting this fume to a moderate heat in order to expel its soluble contents more volatile than zinc, treating the remaining product with dilute sulphuric acid as a solvent and finally subjecting the resulting solution to the action of an electric current to precipitate the zinc.

—Described in Met. and Chem. Eng., vol. 9, p. 618. Nov., 1911.

1829 475,402. Process of obtaining metallic zinc from sulphite of zinc by electrolysis.—**Theodore Lange,** Brieg, Germany Filed June 4, 1890. Issued May 24, 1892.

The process of obtaining zinc from its ores, which consists in disintegrating and roasting the ore, mixing it with hot water, moving the body of ore and water through a closed vessel, causing the hot sulphurous gases from the ore-roasting process to move in the opposite direction through the ore, delivering the treated ore and water to a filter, drawing off the resulting solution of zinc sulphite and throwing down the zinc by passing an electric current through the solution.

1830 495,637. Process of extracting zinc by electrolysis.—**Johannes Pfleger,** Frankfort-on-the-Main, Germany. Filed August 24, 1892. Issued April 18, 1893.

The process of obtaining zinc by electrolysis out of a zinc-containing anode which consists in adding to the bath a basic-zinc-salt solution adapted to act as electrolyte, to which basic zinc-salt solution a conducting neutral salt has been added.

—Described in Zeits. f. Elektrochem., vol. 1, p. 19. April 15, 1894.

1831 512,361. Art of producing metallic zinc.—**Parker C. Choate,** New York, N. Y., assignor to the Electrical Zinc Company, of New Jersey. Filed Jan. 21, 1892. Issued Jan. 9. 1894.

The process of producing from an impure solution of zinc salts, a zinc electrolyte free from depositable impurities, which consists in subjecting the solution to the action of an electric current to precipitate and deposit the depositable impurities and neutralizing the acid set free in the bath with an oxidized zinc fume free from its more volatile soluble constituents.

—Described in Met. & Chem. Eng., vol. 10, p. 62. Jan., 1912.

1832 518,711. Producing metallic zinc.—**Parker C. Choate,** New York, N. Y., assignor to the Electrical Zinc Company. Filed Dec. 9, 1891. Issued April 24, 1894.

The process of producing commercially pure metallic zinc which consists in immersing in a zinc sulphate electrolyte containing chlorine, a zinc anode so prepared as to contain no metal which is both soluble in such electrolyte and depositable by zinc upon itself therefrom, and depositing the zinc by electrolysis.

—Described in Met. & Chem. Eng., vol. 10, p. 122. Feb., 1912.

1833 518,732. Art of producing metallic zinc.—**Parker C. Choate,** New York, N. Y., assignor to the Electrical Zinc Company. Filed Jan. 21, 1892. Issued April 24, 1894.

The process of continuously producing metallic zinc by electrolysis, which consists in depositing the zinc from an acidulated solution of a zinc salt, drawing off from the bath the free acid liberated therein, dissolving in such acid oxidized zinc in the state of fume, freed from its more volatile soluble impurities and returning the solution thus formed to the bath from time to time, as required to maintain the electrolyte.

—Described in Met. & Chem. Eng., vol. 10, p. 122. Feb., 1912.

1834 537,179. Electrolysis.—**Henry Blumenberg, Jr.,** Mount Vernon, N. Y. Filed March 30, 1894. Issued April 9, 1895.

The improvement in the art which consists in placing an electrolyte containing a haloid salt in a vat, electrolyzing the same thereby setting free the halogen under pressure in the positive compartment and the base without pressure in the negative compartment, leading the halogen into a gas holder and applying additional fluid pressure therein, and the base into a tank, and bringing the halogen from the gas holder to the tank containing the base.

1835 546,328. Anode for electrolytical apparatus.—**Carl Hoepfner,** Giessen, Germany. Filed March 26, 1894. Issued September 17, 1895.

An anode for electrolytical apparatuses consisting of a conductive substance, the surface of which anode contains in minimo about ten per cent silicium, so as to render such anode proof against the action of liquids or gases to which it may be exposed, particularly against the action of chlorine.

1836 546,873. Process of treating zinc-bearing ores.—**Edgar A. Ashcroft,** Broken Hill, New South Wales. Filed August 17, 1894. Issued Sept. 24, 1895.

The process for the treatment of zinc bearing ores and zinc bearing products, which consists in first leaching the oxidized ore with a solution containing a ferric salt, to precipitate the iron from said solution, and dissolve the zinc, secondly electrolyzing the resulting zinc-bearing solution by first passing it around metallic cathodes to precipitate the zinc from the said zinc bearing solution, and then around iron anodes to impart a ferrous salt to the solution, and subsequently raising the ferrous salt to the ferric state and thereby regenerating the original ferric salt solution.

—Described in Met. & Chem. Eng., vol. 10, p. 322. May, 1912.

1837 582,923. Electrolytic apparatus.—**Alfred E. Hunt,** Pittsburgh. Filed Dec. 4, 1895. Issued May 18, 1897.

1838 585,355. Process of obtaining metallic zinc and copper from ores.—**Charles A. Burghardt** and **Gilbert Rigg,** Manchester, England. Filed June 1, 1896. Issued June 29, 1897.

The improved process of recovering metallic zinc from zinc ores which consists in treating the roasted and ground ores with an ammoniacal solution, then precipitating the iron dissolved in the resultant liquid by the addition of hydrated oxide of tin, and in finally effecting the electrolytic deposition of the metallic zinc.

—Described in Met. & Chem. Eng., vol 10, p. 570. Sept., 1912.

1839 585,359. Process of obtaining porous metals by electrolysis.—**Ludwig Hoepfner,** Berlin. Filed Oct. 5, 1896. Issued June 29, 1897.

An electrolytic process of obtaining a metal plate which consists in electrically precipitating a porous or spongy metal, and stiffening the same by precipitating thereupon a denser metal.

1840 592,055. Process of treating ores.—**Ernest C. Ketchum,** Boston. Filed Nov. 21, 1896. Issued Oct. 19, 1897.

The process of treating mixed sulphide ores containing lead and zinc, which consists in first roasting the ores, then subjecting the roasted ores to the action of a solution of caustic alkali in the presence of heat to remove from the ores the lead and zinc, then subjecting the caustic solution containing the lead and zinc to electrolytic action in the presence of heat to remove the lead, in a cell or cells in which the anode is immersed in a solution that is free from lead and that is separated by a porous medium from the electrolyte containing the lead and zinc, and finally subjecting the solution in which the zinc remains to electrolytic action, also in the presence of heat, to remove the zinc, employing electric currents of different electromotive force in effecting the successive decompositions.

—Described in Met. & Chem. Eng., vol. 10, p. 571. Sept., 1912.

1841 594,611. Process of and apparatus for removing zinc from zinciferous ores.—**Stephen M. Emmons,** New York. Filed March 6, 1896. Issued Nov. 30, 1897.

The process of treating zinciferous ores which consists in pulverizing and roasting the ore, leaching it in a series of vessels through which the solution flows continuously, and subjecting the contents of each vessel intermittently to electrolytic action, whereby the solution is rendered alternately acid and neutral or more acid and less acid in contact with each body or ore.

—Described in Met. & Chem. Eng., vol. 10, p. 571-72. Sept., 1912.

1842 598,180. Apparatus for electrolytically producing zinc.—**Carl Hoepfner,** Giessen, Germany. Filed Oct. 7, 1893. Issued Feb. 1, 1898.

An electrolytic apparatus comprising a vessel containing a zinc-chloride solution, a suitable insoluble anode, and a discoidal revoluble cathode, the latter dipping partly into said solution, means for preventing chlorine bubbles formed at the anode from coming into reactive contact with the cathode and the source of electricity respectively.

1843 600,351. Treatment of metalliferous ores and products.—**Edgar A. Ashcroft,** Melbourne, Australia. Filed Feb. 4, 1897. Issued March 8, 1898.

The improved process consisting in circulating a zinc-bearing solution first around the metallic cathodes of a system of vats of an electrolytic apparatus, then around the anodes of the same system of vats, said anodes consisting of the matte of the products resulting from the preliminary furnace treatment of products or ores containing copper and iron, whereby a part or the whole of the zinc content is deposited as metallic zinc and the solution becomes charged with copper and iron, next around the metallic cathodes of another system of vats of the said electrolytic apparatus, and finally around the carbon anodes of the same system of vats of the said electrolytic apparatus, whereby the whole or a part of the copper content is deposited and the iron completely or partially raised to the ferric condition.

—Described in Met. & Chem. Eng., vol. 10, p. 704. Oct., 1912.

1844 623,888. Electrodeposition of zinc upon iron.—**Sherard O. Cowper-Coles,** London, England. Filed Dec. 31, 1897. Issued April 25, 1899.

The process of depositing zinc electrolytically and preventing the formation of zinc sponge, by placing in an electrolytic cell containing suitable insoluble anode and cathode plates and electrolyte containing zinc sulphate and iron sulphate and passing through the cell an electric current, the oxygen liberated at the anode when zinc is deposited preventing the formation of hydrogen compounds of zinc or zinc sponge.

1845 629,685. Electrolytic production of zinc or other metals.—**Carl Hoepfner,** Berlin. Filed July 16, 1896. Issued July 25, 1899.

A process which consists in placing a lead or copper anode in a solution capable of dissolving the same, placing a suitable cathode in a solution similar to that at the anode but containing also zinc, separating the two solutions by a suitable diaphragm, passing a current from the anode through both solutions to the cathode, thereby bringing lead or copper into solution at the anode and depositing zinc at the cathode, precipitating the lead or copper dissolved in the anode solution by adding a zinc compound thereto and conveying the resulting solution to the cathode compartment.

—Described in Met. & Chem. Eng., vol. 11, p. 59. Jan., 1913.

1846 639,579. Process of recovering zinc from refractory zinc-bearing ores.—**John Jones,** East Melbourne, Victoria. Filed Feb. 17, 1898. Issued Dec. 19, 1899.

The process which consists in placing in the anode compartment of a cell having a suitable diaphragm, a mixture of sulphate of zinc and sulphate of ammonium, placing in the cathode-compartment an acid solution containing sulphate of zinc, passing an electric current through both solutions whereby zinc and ammonium are set free at the cathode, and continuously adding to the cathode solution sufficient acid solution containing zinc sulphate to neutralize the ammonium liberated in said solution and to maintain in the solution a low degree of acidity.

—Described in Met. & Chem. Eng., vol. 11, p. 60. Jan., 1913.

1847 644,029. Process of electrodeposition of metals.—**Sherard O. Cowper-Coles,** London, England. Filed Aug. 28, 1899. Issued Feb. 20, 1900.

In the electrodeposition of metals, the process consisting in passing an electric current from an anode to a cathode through an electrolyte containing the metal to be deposited, and at the same time rotating the cathode at such a high rate of speed as will cause the hydrogen bubbles to be thrown off from the cathode and give such friction between the metal deposits on the cathode and the electrolyte as to yield tough and smooth deposits.

1848 649,151. Apparatus for electrolytically extracting metals from refractory ores.—**Wm. Wright,** N. Y. Issued May 8, 1900.

—Described in Met. & Chem. Eng., vol. 11, p. 60. Jan., 1913.

1849 650,646. Apparatus for electrolytic reduction of ores.—**Frederic H. Long,** Chicago, Ills. Filed June 22, 1898. Issued May 29, 1900.

In electrolytic apparatus, the combination with the reducer vessel, of the open partition extended across said vessel, the anode projected past the partition, the terminal cathode, the interposed diaphragm and suitable means for circulating the ore charge between the anode and diaphragm, substantially as described. 9 claims.

1850 655,783. Electrolytic apparatus for decomposing metallic salts.—**Carl Kellner,** Vienna, Austria. Filed March 3, 1896. Issued Aug. 14, 1900.

An external vessel for containing an electrolyte, suitable anodes, a mercury cathode suspended above the bottom of said vessel by suitable means, a chambered structure dipping into the cathode, means for moving said structure through the cathode and means for placing one or more chambers of the chambered structure in communication with the external vessel.

1851 656,305. Process of electrolytically extracting zinc from ores.—**Wilhelm Strzoda,** Falence, Germany. Filed Jan. 20, 1899. Issued Aug. 21, 1900.

The process consists in placing the disintegrated ore in its natural state in an electrolytic vat containing an aqueous alkali-metal solution capable of dissolving the ore with the production of a zincate and in direct contact with the cathode and closing the circuit through the vat, thereby precipitating zinc and the alkali metal at the cathode, the alkali metal reacting with the water, to regenerate the solvent solution.

—Described in Met. & Chem. Eng., vol. 11, p. 116. Feb., 1913.

1852 657,646. Apparatus for reclaiming tin and zinc from tinned and zinc scrap.—**George B. Cruickshank,** Birmingham, **Herbert R. S. Coleman,** Smethwick, and **Percival Cruickshank,** Birmingham, England. Filed May 23, 1900. Issued Sept. 11, 1900.

In apparatus for reclaiming tin or zinc from tinned or zinc scrap by the use of a chemical solution and electricity, the combination of a vat, having suspended therein a revoluble reel with flanges carried in bearings, with the circumferential revoluble perforated anode-drums journaled, such drums and their interiors being connected to the positive pole of a battery or dynamo, and the cathode-plates connected to the negative pole of a battery or dynamo.

1853 664,269. Process of recovering zinc.—**Carl Hoepfner,** Frankfort-on-the-Main, Germany. Filed Nov. 18, 1897. Issued Dec. 18, 1900.

The process which consists in reacting upon zinc carbonate or a material containing it, with a solution of calcium chloride at a temperature above normal and a pressure above atmospheric recovering a portion of the zinc electrolytically and the remaining zinc as a hydroxide by means of lime, concentrating the solution and returning it into the cycle of operations. 7 claims.

—Described in Met. & Chem. Eng., vol. 11, p. 116. Feb., 1913.

1854 665,953. Process of electrolyzing soluble salts.—**Antoine J. O. Chalandre** and **Louis J. B. A. Colas,** Paris, and **Charles Gerard,** Seveux, France. Filed March 21, 1899. Issued Jan. 15, 1901.

The process consists in passing an electric current through a soluble salt from an anode to a cathode, combining, outside of the apparatus, part of the gases from the cathode and anode compartments, to form an acid, then introducing the acid thus formed into the anode compartment, where it immediately decomposes to counteract or annul detrimental secondary reactions and liberate or recuperate the gas evolved at the positive pole which has served in the formation of the acid.

1855 669,926. Process of electrolytical extraction of metals.—**Carl Hoepfner,** Frankfort-on-the-Main, Germany. Filed Sept. 27, 1899. Issued March 12, 1901.

A process which consists in placing a lead or copper anode in a solution capable of dissolving the same, placing a suitable cathode in a solution similar to that at the anode but containing also zinc, containing however no metal more electronegative than zinc, interposing a similar third solution of less solution-pressure than that at the cathode, separating the solutions by suitable diaphragms, maintaining their temperature above normal, passing a current from the anode through the solutions to the cathode, thereby bringing the lead or copper into solution at the anode and depositing zinc at the cathode, precipitating the lead from the anode and intermediate solution by means of zinc oxide and carbonic acid and conveying the resulting solution to the cathode-cells.—12 claims.

—Described in Met. & Chem. Eng., vol. 11, p. 171. March, 1913.

1856 674,809. Process of treating zinc-bearing ores for obtaining zinc, etc.—**Sherard O. Cowper-Coles,** London, England, assignor to the Cowper-Coles Metal Extraction Syndicate.

Ltd., Mellanear Haeyle, England. Filed July 23, 1898. Issued May 21, 1901.

A process for the treatment of complex zinc ores, such as those known as "Broken Hill" ore, consisting in mixing with the said ore prior to the roasting a quantity of zinc blende, copper sulphide ore or tin ore tailings thereof, then roasting it to a "dead roast" then crushing and screening it and placing it in vats where it is leached with a weak solution of sulphuric acid to abstract the zinc and copper, then passing such solution containing zinc sulphate and copper sulphate through a body of carbon and an electropositive metal to recover the copper and then electrolyzing the remaining solution to recover the zinc; the said leaching solution after its strength has been adjusted, being returned to the leaching-vats for use over again. 6 claims

1857 678,816. Process of recovering zinc.—**Albert J. Shinn,** Philadelphia, Pa. Filed June 4, 1900. Issued July 16, 1901.

The process of recovering zinc from a solution of any of its compounds, said process consisting of electrolytically decomposing said solution, collecting the zinc thrown out as an amalgam upon a stream of mercury flowing over a metal plate, separating the thick or pasty amalgam from the surplus mercury and liquid amalgam during the operation of the process, and returning this liquid to be used repeatedly in the above process.

1858 690,295. Process of extracting zinc from waste products of roasted pyrites.—**Carl Kellner,** Vienna, Austria-Hungary. Filed Oct. 13, 1900. Issued Dec. 31, 1901.

Consists in converting the zinc compounds into sulphite of zinc by means of sulphurous acid, converting the sulphite into sulphate of zinc, mixing therewith a chloride of a metal of the alkalies or alkaline earth, thereby forming chloride of zinc and sulphate of an alkali metal, placing therein suitable electrodes and passing an electric current, thereby depositing zinc at the cathode and liberating chlorine at the anode. 6 claims. Patented also in England, no. 7028 of 1900.

--Described in Jour. Soc. Chem. Ind., vol. 20, p. 367. April 30, 1901.

1859 692,531. Electrolytic cell.—**Ernest A. Le Sueur,** Rumford Falls, Me., assignor to the Electro-Chemical Company. Issued Feb. 4, 1902.

1860 697,831. Method of recovering metals by electrolysis.—**Hans A. Frasch,** Hamilton, Canada. Issued April 15, 1902.

A process of recovering metals by electrolysis which consists in electrolyzing a double salt of ammonia and metals whose hydroxides are soluble in ammonia, in the presence of a soluble anode and an anode electrolyte (anolyte) containing metals different from the one contained in the cathode electrolyte (catholyte) but free from ammonia.

1861 700,563. Process of extracting metals from ores and scrap containing same.—**Samuel S. Sadtler,** Philadelphia, Pa. Filed July 10, 1900. Issued May 20, 1902.

The process of obtaining zinc from sulphide ores, said process consisting in treating said ores with a solution formed by treating a caustic alkali with one of the halogens and decomposing the resulting solution in an electrolytic cell, the metal being deposited on a suitable cathode.

—Described. Met. & Chem. Eng., vol. 11, p. 226. April, 1913.

1862 701,215. Method of obtaining zinc by electrolysis.—**Ludwig Mond,** London, England. Filed Aug. 12, 1901. Issued May 27, 1902.

A method of obtaining zinc in a solid metallic condition which consists in depositing the zinc on separate cathodes by electrolysis and simultaneously therewith subjecting the deposited zinc upon one cathode to a longitudinal and transverse rubbing action of the zinc deposited upon the other cathode under pressure.

1863 701,216. Apparatus for obtaining zinc by electrolysis.—**Ludwig Mond,** London, England. Filed March 4, 1902. Issued May 27, 1902.

An apparatus for obtaining zinc by electrolysis, the combination of a number of cylindrical cathodes rotating in contact with each other within an electrolytic bath, means for pressing the cylinders against each other and means for producing a longitudinal rubbing action between the cylinders.

1864 703,857. Electrometallurgical treatment of zinc ores and especially blende.—**Constantin J. Tossizza,** Paris, France. Filed Aug. 6, 1901. Issued July 1, 1902.

For the electrolysis of the sulphate and other salts of zinc, the process whereby a practical reduction of the voltage below two and three-tenths is obtained by the aid of sulphurous acid as a depolarizer, the said process being divided into two parts to avoid the decomposition of said sulphurous acid and consisting as to one part in the electrolysis of the zinc salt with corresponding solution of copper anodes and formation of copper salt, and as to the second part in the electrolytic reconstitution of the said copper anodes by decomposition of the so-formed copper salt in a solution primarily charged with sulphurous acid. Patented in England, no. 14,825 in 1901.

—Described in Met. & Chem. Eng., vol. 11, p. 301. May, 1913.

1865 736,565. Process of zincing objects by electrolysis.—**Ignaz Szirmay,** Budapest, Austria-Hungary. Filed Nov. 12, 1900. Issued Aug. 18, 1903.

The method of zinc-plating objects which consists in placing such objects as cathode with a suitable anode in an electrolyte of an aqueous solution of a zinc salt, dextrose and a mixture of sulphates of aluminium and magnesium and passing an electric current. Patented also in England, no. 19,659 of 1900.

1866 742,442. Process of electrodepositing metals.—**Woolsey M. Johnson,** Hartford, Conn. Filed Jan. 13, 1903. Issued Oct. 27, 1903.

The method which consists in subjecting the electrolyte in the neighborhood of the cathode to such pressure as will remove contained gases, and electrodepositing a metal therefrom in reguline form. 10 claims.

1867 742,443. Electrolytic apparatus.—**Woolsey M. Johnson,** Hartford, Conn. Filed Jan. 13, 1903. Issued Oct. 27, 1903.

1868 745,378. Electrolytic refining of zinc.—**Heinrich Paweck,** Vienna, Austria-Hungary. Filed March 7, 1902. Issued Dec. 1, 1903.

The electrolytic process of depositing zinc by electrolyzing in a bath containing zinc salts, conductive salts and boron compounds. Patented also in England, no. 1688 of 1902; in France, no. 318,163.

1869 757,817. Process of electrically extracting copper and zinc from ores.—**Stanislaw Laszczynski,** Kielce, Russia. Filed Oct. 10, 1902. Issued April 19, 1904.

Process for electrolytically obtaining metals, especially copper and zinc, out of their ores by means of insoluble anodes, consisting in tightly wrapping the insoluble anode in a porous and perfectly permeable envelope or other suitable material, the thickness of which is in inverse proportion to the applied density of current, for the purpose of preventing anodic oxidation of the cathodes. See also item 1749.

1870 791,401. Process of extracting zinc from its ores.—**Anson G. Betts,** Troy, N. Y. Filed Feb. 20, 1905. Issued May 30, 1905.

The process of extracting zinc from its ores which consists in extracting zinc therefrom as a solution of zinc sulphate, electrolyzing the solution with a mercury cathode for the production of a zinc-mercury alloy, and extracting zinc from the alloy and depositing zinc on a suitable cathode by electrolysis of a solution of zinc chloride.

1871 798,790. Electrolytic process.—**Carl Hering,** Philadelphia, Pa. Filed July 13, 1901. Issued Sept. 5, 1905.

In an electrolytic process in which there exists in solution in the electrolyte an ingredient which is objectionable because hindering the desired electrolysis, the method of making such objectionable ingredient inert which consists in electrolyzing the solution with an electrode of a material with which said ingredient will combine to form a chemical compound which is inert in the desired electrolytic process and is thereby removed from further action. Zinc is deposited from an electrolyte containing its salt or sulphate, by using an anode of spongy lead. 21 claims.

1872 831,843. Process for the electrolytic production of zinc.—**Victor Engelhardt,** Vienna, Austria-Hungary, assignor to Siemens & Halske Aktiengesellschaft Berlin. Germany. Filed Sept. 14, 1904. Issued Sept. 25, 1906.

The process for the electrolytic production of zinc from sulphate solutions which consists in emplying at the anode a current density of from twenty to fifty times that of the current density at the cathode. Patented also in England, no. 16,396 of 1904.

—Described in Electro. Chem. & Met. Ind., vol. 4. pp. 416-17. Oct., 1916.

1873 905,785. Electrolytic solution for zinc plating.—**Celestino Bianco,** New York, N. Y. Filed July 16, 1907. Issued Dec. 1, 1908.

An electrolyte for the electro deposition of zinc, containing compounds of zinc and iron and an organic-acid salt of an alkali metal.

1874 923,411. Manufacture of zinc dust.—**Sherard O. Cowper-Coles,** London, England. Filed Aug. 2, 1907. Issued June 1, 1909.

A process for the production of zinc dust, consisting in electrodepositing zinc from a caustic soda solution upon a revolving disk upon which the zinc is deposited in the form of a sponge and is continuously removed, and in then drying the spongy zinc so produced in a reducing atmosphere. Patented also in England, no. 13,977 of 1907.

1875 935,109. Apparatus for the electrolysis of aqueous solutions. —**Max Huth,** Charlottenburg, near Berlin, Germany, assignor to Siemens & Halske, A.-G., Berlin. Filed Jan. 5, 1909. Issued Sept. 28, 1909.

In an apparatus for the electrolysis of aqueous solutions such as zinc sulphate solutions or solutions of other sulphates, an anode consisting of massive, artificially produced peroxide of manganese, coated (or not) with ceresin, and free from constituents susceptible to the action of the electrolyte. 6 claims.

1876 935,250. Electrolytic winning of zinc from solutions of zinc sulphate.—**Victor Engelhardt** and **Max Huth,** Charlottenburg, Germany, assignors to Siemens & Halske, Aktiengesellschaft, Berlin. Filed May 25, 1907. Issued Sept. 28, 1909.

In the process of electrolytically obtaining zinc from sulphate solutions, the process of preventing re-dissolution of the zinc deposit which consists in employing for the electrolysis an anode of compact lead peroxide free from constituents soluble in the electrolyte. Patented also in France, no. 375,140.

—Described in Metallurgie, vol. 7, p. 1. Jan. 8, 1910.
—Described in Min. Mag., vol. 2, p. 123. Feb., 1910.
—Described in Min. Mag., vol. 2, p. 314. April, 1910.

1877 961,514. Process for treating zinciferous substances.—**Guido Mojana,** Milan, Italy. Filed Dec. 14, 1906. Issued June 14 1910.

A process for the treatment of zinciferous substances at a comparatively low temperature, consisting in subjecting the same to the action of chlorine in the presence of porous carbon and steam, removing the carbon from the mass thus obtained, lixiviating, filtering, and treating the liquid residuum with oxidizing agents and substances containing oxide of zinc, to obtain zinc chloride, and electrolyzing the zinc chloride to obtain metallic zinc. Patented also in England, no. 28,575 of 1906.

1878 967,200. Electrolyte and method of electro-depositing zinc. —**Edward F. Kern,** Knoxville, Tenn., assignor of one-half to Percy S. Brown, New York, N. Y. Filed Sept. 1, 1909. Issued Aug. 16, 1910.

The herein described process of electrodepositing zinc which consists in electrolyzing a solution containing fluosilicate of zinc, fluo-silicate of a metal which stands higher in the solution pressure series than zinc, an organic addition agent (grape-sugar), and adding ammonium fluoride thereto from time to time during the electrolysis. 8 claims.

1879 998,379. Process of electrolytic refining of zinc.—**Kunigoro Namekawa, Jishichiro Miyazama, Kumazo Miyabara,** and **Shotaro Emura,** Tokyo, Japan. Filed March 1, 1911. Issued July 18, 1911.

The process of electrolytically forming thick deposits of zinc from a zinc sulphate solution employing a plurality of lead anodes and suitable cathodes, which consists in adding to said solution a compound of vegetable origin which has been heated almost to the point of carbonization; in passing a current through said solution from said anodes to said cathodes; in passing a current at intervals from some of said anodes through the solution to certain other of said anodes to strip the latter of any lead sulphates that may have formed thereon: and in then passing a current from said last mentioned anodes to said first group of anodes to strip any sulphates from said first group of anodes. Patented also in England, no. 5,967 of 1911; in France, no. 430,167.

—Described in Metallurgie, vol. 9, p. 338. May 22, 1912.

1880 999,568. Electrolyte and method of depositing zinc.—**Edward Kern,** Knoxville, Tenn., assignor of one-half to Percy S. Brown, New York, N. Y. Filed Dec. 18, 1909. Issued Aug. 1, 1911.

A process of electrodepositing zinc, which consists in electrolyzing a solution containing chloride of zinc, chloride of ammonium, another metallic chloride and grape sugar. 21 claims.

1881 999,655. Electrolyte for depositing zinc.—**Edward F. Kern,** New York, N. Y., assignor of one-half to Percy S. Brown, New York, N. Y. Filed Oct. 11, 1910. Issued Aug. 1, 1911.

An electrolyte comprising chloride of zinc, and a double chloride of aluminum and another metal. 9 claims.

1882 1,006,330. Obtaining zinc and/or copper from complex ores or the like.—**John R. Williams, Henry W. Bradley** and **Benjamin Bradley,** Sheffield, England. Filed Aug. 9, 1909 Issued Oct. 17, 1911.

A process for the extraction of zinc, copper, or both including leaching the ore with dilute solution of sulphuric acid until the acid is exhausted, reacidifying the solution to substantially its initial concentration and repeating the operations until a solution containing a substantial quantity of metallic sulphate is formed, electrolyzing the solution removing therefrom sufficient metal to produce a solution of the initial acidity and employing this for further leaching. Patented also in England, no. 26,711 of 1908.

—Described in Met. & Chem. Eng., vol. 9, p. 662. Dec., 1911.

1883 1,017,981. Electroplating with zinc.—**Auguste Arsene Lemetre,** Paris. Filed May 29, 1911. Issued Feb. 20, 1912.

A process of electroplating with zinc which comprises preparing a bath comprising zinc sulphate, water, and materials capable of producing ammonium chloride, sodium sulphate and sulphuric acid in the bath, and passing an electric current through said bath, containing an article to be electroplated, thus forming an adherent deposit of zinc upon such article.

1884 1,052,256. Electrolysis of metal salt solutions.—**Noak Victor Hybinette,** Kristiansand, Norway. Filed Jan. 5, 1912. Issued Feb. 4, 1913.

Diaphragms for use in the electrolytic deposition of metals from aqueous metal salt solutions, comprising a fibrous filtering material supported by a structure having leaden parts exposed to the action of the electrolyte. Patented also in France, no. 438,846.

1885 1,055,157. Electrolytic recovery of zinc and manganese.—**Andrew Gordon French,** Nelson, British Columbia, Canada. Filed Sept. 4, 1912. Issued March 4, 1913.

A process for the recovery of pure metallic zinc and manganese dioxide, said process comprising the passage of an electric current of from two and a half to four and a half volts from a lead anode to a zinc cathode immersed in a solution containing sulphate of zinc, sulphate of magnesium and neutral sulphate of sodium.... The electrolyte after being acted upon being continuously delivered to the leaching tank from which the original supply was obtained and continually replaced in the electrolytic tank by a supply drawn from the same leaching tank.

—Described in Met. & Chem. Eng., vol. 11, p. 293. May, 1913.

1886 1,055,158. Electrolytic recovery of zinc and manganese.—**Andrew Gordon French,** Nelson, British Columbia, Canada. Filed Sept. 4, 1912. Issued March 4, 1913.

A process for the recovery of pure metallic zinc and manganese dioxide which comprises the electrolytic decomposition of a solution containing sulphate of zinc, sulphate of manganese and neutral sulphate of sodium, the electrolyte after being acted upon being treated to effect the regeneration of the required sulphate of manganese by treating dioxide of manganese in suspension by sulphurous acid gas or a sulphurous acid solution, and then delivering the electrolyte after being regenerated to the leaching tank from which the original supply was obtained and replaced in the electrolytic tank by a supply drawn from the same leaching tank. See also items 1780 to 1796.

—Described in Met. & Chem. Eng., vol. 11, p. 293. May, 1913.

1887 1,059,233. Electrodeposition and refining of zinc.—**Urlyn Tainton,** Manchester, and **John N. Pring,** Sandbach, England. Filed March 16, 1912. Issued April 15, 1913.

The herein described process for the electrolytic deposition of metallic zinc which consists in forming a solution of zinc and adding to the solution from 10 to 30 per cent of acid and a small proportion of gum tragacanth and electrolyzing the solution with a current of high density. 12 claims. Patented also in England no. 7,235 of 1911. See also item 1809.

1888 1,107,309. Process for the electrolysis and treatment of sulphate liquors.—**Edwin James Hunt,** Oldbury, and **William Thomas Gidden,** Warley, England, assignors to Chance and Hunt, Ltd. Filed March 21, 1914. Issued Aug. 18, 1914.

In the process for the electrolysis of a zinc sulphate solution containing free sulphuric acid by the aid of a lead anode so conducting the process that the free particles of undissolved lead compounds derived from the anode cannot pass to the cathode while the electrolyte at both anode and cathode remains the same.

1888a 1,089,412. Treatment of refractory zinc ores.—**P. C. C. Isherwood,** Bushey Heath, England. Filed Oct. 18, 1912. Issued March 10, 1914.

See item 586; also item 1717.

1889 1,111,201. Process of extracting zinc from its ores or compounds.—**Ernest E. Watts,** Kingston, Ontario, Canada. Filed Nov. 20, 1913. Issued Sept. 22, 1914.

A process of extracting zinc which comprises mixing a material containing a high percentage of zinc in a non-elemental condition with a solution of zinc sulphate relatively free from dissolved iron compounds, in proportions to form thin paste, charging said paste into the anode compartment of an electrolytic cell containing an electrolyte consisting of a highly concentrated solution of zinc sulphate, said solution being relatively free from iron compounds, and then passing a suitable electric current through said cell, whereby the zinc is deposited at the cathodes.

1889a 1,148,798. Electrolytic refining or extracting process.—**Francis R. Pyne,** Elizabeth, N. J., and **Henry M. Green,** Chrome, N. J., assignors to U. S. Metals Refining Co. Filed Apr. 20, 1915. Issued Aug. 3, 1915.

In an electrolytic refining or extracting process wherein the electrolyte contains more than one constituent, allowing stratification to take place to a determined or desired degree, and leading off portions of the electrolyte separately from different strata. 11 claims. See also item 1720.

1889b 1,154,601. Extraction, purification, and electrolytic precipitation of metallic zinc from smelter fumes, zinc ores and the like.—**Otto Best,** San Francisco. Filed Sept. 16, 1911. Issued Sept. 28, 1915.

See item 401; also items 594 and 1702.

1890 1,163,286. Process of recovering zinc from an acid sulphite solution.—**Charles S. Vadner,** Salt Lake City, Utah. Filed May 26, 1914. Issued Dec. 7, 1915.

The process of recovering zinc from an acid sulphite solution which consists in electrolyzing the solution, partially neutralizing the acid that may be formed, and continuously electrolyzing for the recovery of the zinc and elimination of the SO_2 gas.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 124. Jan. 31, 1916.

—Described in Min. & Sci. Press, vol. 112, p. 483. April 1, 1916.

1891 1,163,911. Electrolysis.—**Clarence A. Hall,** Mount Airy, Pa. Filed March 6, 1913. Issued Dec. 14, 1915.

The process of maintaining the free anion concentration of a zinc electrolyte constant during electrolysis which consists in carrying on electrolysis in the presence of a finely divided substance which is insoluble in the absence of the current and which in the presence of the current combines with the liberated anions, forming a compound electrically inert in the electrolyte, and continually and thoroughly agitating the finely divided substance and electrolyte during electrolysis. See also items 1653 and 1712.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 186. Feb. 15, 1916.

1892 1,167,594. Electrolytic cell.—**Lewis E. Porter,** Los Angeles. Filed May 11, 1914. Issued Jan. 11, 1916.

See also item 1654.

1893 1,167,700. Process of extracting zinc from its ores.—**Frederick Laist** and **Frederick F. Frick,** Anaconda, Mont. Filed Aug. 13, 1915. Issued Jan. 11, 1916.

A cylical process of extracting zinc from oxidized ores thereof containing iron, which consists in leaching the ore with dilute sulphuric acid, oxidizing the ferrous sulphate by means of a manganese compound in a state of oxidation higher than the manganous state, precipitating the ferric iron, electrolytically depositing the zinc from the purified solution with insoluble anodes, and utilizing the resulting acid solution containing manganese in its higher states of oxidation for the extraction of zinc from additional portions of the ore. 6 claims.

—Described in Jour. Soc. Chem. Ind., vol. 13, p. 314. March 15, 1916.

—Described in Met. and Chem. Eng., vol. 14, p. 220 Feb. 15, 1916.

1894 1,167,701. Process of recovering zinc from its ores.—**Frederick Laist** and **Frederick F. Frick,** Anaconda, Mont. Filed Sept. 9, 1915. Issued Jan. 11, 1916.

A cyclical process of recovering zinc from oxidized ores thereof containing iron, which consists in leaching the ore with an acid reagent oxidizing the dissolved ferrous salt, purifying the solution by adding thereto an excess of calcine in presence of an agent capable of oxidizing ferrous iron, and electrolytically regenerating the oxidizing agent with simultaneous deposition of metallic zinc.

—Described in Jour. Soc. Chem. Ind., vol. 13, p. 314. March 15, 1916.

—Described in Met. & Chem. Eng, vol. 14, p. 220. Feb. 15, 1916.

1895 1,171,255. Treatment of ores.—**Otto Carl Rudolph,** Aldwych, London, England, assignor to Otto Stalmann, Salt Lake City, Utah. Filed Dec. 16, 1914. Issued Feb. 8, 1916.

A process for the treatment of complex ores containing volatile metals such as zinc, lead, and silver in combination with sulphur, consisting in fusing the ore charge and partially volatilizing its metallic constituents by electrical means, blowing air under pressure through the liquid charge to volatilize the remaining part of its volatile metallic constituents, dissolving the volatile zinc constituent and precipitating the volatile lead constituent given off during the fusing and blowing operations by a liquid, removing the precipitated lead from said liquid and finally recovering the metallic zinc by electrolytic treatment. 6 claims. Patented also in England, no. 29,156 of 1913.

1896 1,176,467. Process of treating zinc ores.—**Court C. Titus** and **William J. Barenscheer,** Helena, Mont., assignors to New England Electro-Chemical Metals Company, Boston, Mass. Filed Aug. 31, 1914. Issued Feb. 29. 1916.

In a cyclical process of treating complex ores containing zinc, the steps which consist in chloridizing the dry ore in presence of sodium chloride, extracting the soluble chlorides, precipitating the metal contents of the solution with ultimate replacement of their chlorides by sodium chloride, electrolyzing the resulting sodium chloride solution, applying the evolved chlorine to the treatment of ore entering the cycle, and applying the chlorinated anode-liquor as a solvent for the chlorides derived from said ore. 10 claims.

1897 1,200,025. Process of recovering metals.—**Charles J. Reed,** Glenside, Pa. Filed Aug. 25, 1915. Issued Oct. 3, 1916.

The process of recovering zinc from its aqueous solutions which consists in electro-depositing the metal in a cathode of mercury, dissolving the zinc from the resulting amalgam and simultaneously depositing it on a cathode with which it does not alloy or amalgamate, and compensating the solution of metal by local action from the amalgam anode by supplying thereto the requisite additional quantities of amalgam.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 1223. Dec. 15, 1916.

1898 1,210,017. Electrolytic recovery of zinc from ores and other zinc-bearing materials.—**Urlyn C. Tainton**, Johannesburg, Transvaal, South Africa. Filed Aug. 10, 1915. Issued Dec. 26, 1916.

A continuous process for the electrolytic extraction of metallic zinc from a zinc-bearing material which consists in adding sufficient of the zinc-bearing material to an acid to make a neutral solution, separating the neutral solution from the residue, adding an excess of acid, and electrolyzing said solution by means of a current of high density and thus removing part of the zinc; then removing the solution now highly acid and dividing it into two portions, neutralizing one portion by a further addition of zinc-bearing material, adding a slight excess of zinc-bearing material to the neutral solution to remove any iron or other impurities present, separating the neutral solution from the residue, adding the other portion of the removed solution, and electrolyzing the acid solution so formed; and thereafter repeating the regenerating anl electrolyzing process as described. 9 claims. Patented also in England, no. 11,335 of 1916; in France, no. 479,702. See also item 1811.

—Described in Jour. Soc. Chem. Ind., vol. 36, p. 145. Feb. 15, 1917.

1899 1,235,723. Apparatus for the production of zinc, copper or other metals by electrolysis.—**Marcel Perreur-Lloyd**, Boulogne-sur-Seine, France. Filed May 24, 1915. Issued August 7, 1917.

Apparatus for the production of metals by electrolysis, comprising a tank and a rotary cathode, a shaft on which said cathode is mounted, and means for supporting said cathode shaft, said means comprising a bracket adapted to be attached to the side of the tank, having a stuffing box in the wall of the tank for preventing liquid passing out around such shaft, and having outside of said tank beyond said stuffing box a bearing adapted to support said shaft. 6 claims.

1900 1,235,724. Apparatus for the electrolytic production of zinc, copper, or other metals.—**Marcel Perreur-Lloyd**, Boulogne-sur-Seine, France. Filed Dec. 14, 1915. Issued Aug. 7, 1917.

Apparatus for the production of metals by electrolysis comprising a rectangular vessel of small depth in which are mounted a plurality of rotary cathode mandrels of small diameter and of great length, each surrounded by a perforated lead anode, in the form of an open-topped trough, all the anodes being riveted or connected together and resting on supports disposed in the vessel, wiping impregnating pads of insolubilized animal substance being arranged to travel with an irregular reciprocating motion over the surface of the metal deposited on the cathode cylinders. 7 claims. See also item 1657.

1901 1,241,966. Zinc-extraction process.—**Herbert R. Hanley,** Winthrop, Cal., assignor to Bully Hill Copper Mining and Smelting Company. Filed June 5, 1916. Issued Oct. 2, 1917.

The process of extracting zinc from zinc bearing material containing arsenic, antimony, selenium, tellurium, bismuth or the like, which consists in treating said materials with sulphuric acid, roasting at a temperature at which the zinc compounds are converted to zinc sulphate and arsenic, selenium and the like are volatilized, leaching the product with water to dissolve soluble constituents, electrolyzing the solution to largely decompose the zinc sulphate, forming zinc and sulphuric acid, concentrating the spent liquor, and utilizing the same for roasting with fresh quantities of zinc bearing material. 11 claims.

—Described with abstract in Met. & Chem. Eng., vol 18, p. 485, May 1, 1918.

1902 1,241,967. Electrolytic apparatus.—**Herbert R. Hanley,** Winthrop, Cal., assignor to Bully Hill Copper Mining & Smelting Company. Filed June 5, 1916. Issued Oct. 2. 1917.

An aerating device comprising a receptacle containing a liquid, an air supply pipe, one or more pipes communicating therewith through a non-submerged orifice, said pipes having a submerged orifice of larger diameter than the said non-submerged orifice.

—Described with diagr., in Met. Chem. Eng., vol. 18, p. 485. May 1, 1918.

1903 1,247,179. Electrodeposition and extraction of zinc.—**Urlyn Clifton Tainton,** London, and **John Norman Pring,** Chester, England. Filed Nov. 7, 1916. Issued Nov. 20, 1917.

A continuous process for the electrolytic extraction of metallic zinc from a zinc-bearing material, which consists in adding sufficient of the zinc-bearing material to an acid to make a neutral solution free from any colloid agent, separating the neutral solution from the residue, adding an excess of acid, electrolyzing said solution by means of a current of high density and thus removing part of the zinc, then removing the solution now strongly acid, and dividing it into two portions, neutralizing one portion by further additions of zinc-bearing material, separating the neutral solution from the residue, adding the other portion of the removed solution and electrolyzing the acid solution so formed, and thereafter repeating the regenerating and electrolyzing process as described.

—Described in Met. & Chem. Eng., vol. 18, p. 486. May 1. 1918.

1904 1,251,302. Electrolytic recovery of metals from their solutions.—**Urlyn Clifton Tainton,** Johannesburg, Transvaal, South Africa. Filed July 6, 1915. Issued Dec. 25, 1917.

The process of precipitating metals from solutions which consists in introducing the solution into an electrolytic cell, producing therein a rapid relative movement between the cathode and the solution whereby the metal precipitated on the cathode is detached therefrom and removing the precipitated metal from the cell. 6 claims.

1905 1,255,435. Method of purifying zinc-bearing solutions.—**Frederick Laist** and **James Orr Elton,** Anaconda, Mont., assignors to Anaconda Copper Mining Company. Filed June 16, 1916. Issued Feb. 5, 1918.

In a process of purifying zinc-bearing solutions the step which consists in subjecting the impure solutions to the action of electrolytically deposited zinc sponge. 4 claims.

1906 1,255,436. Process of recovering zinc from ores.—**Frederick Laist** and **James Orr Elton,** Anaconda, Mont., assignors to Anaconda Copper Mining Company. Filed June 16, 1916. Issued Feb. 5, 1918.

A cyclical process of recovering zinc from ores thereof containing arsenic or antimony, consisting in alternately leaching the ore with an acid solvent for zinc, and electrolytically precipitating zinc from the resulting solution, introducing iron into the solution subsequent to the electrolysis from an outside source and in proportion sufficient for the substantial elimination of arsenic and antimony, and removing the iron therefrom, together with the arsenic and antimony, by precipitation in the ferric state prior to the succeeding electrolysis. 5 claims.

—Described in Min. & Sci. Press, vol. 116, p. 824. June 15, 1918.

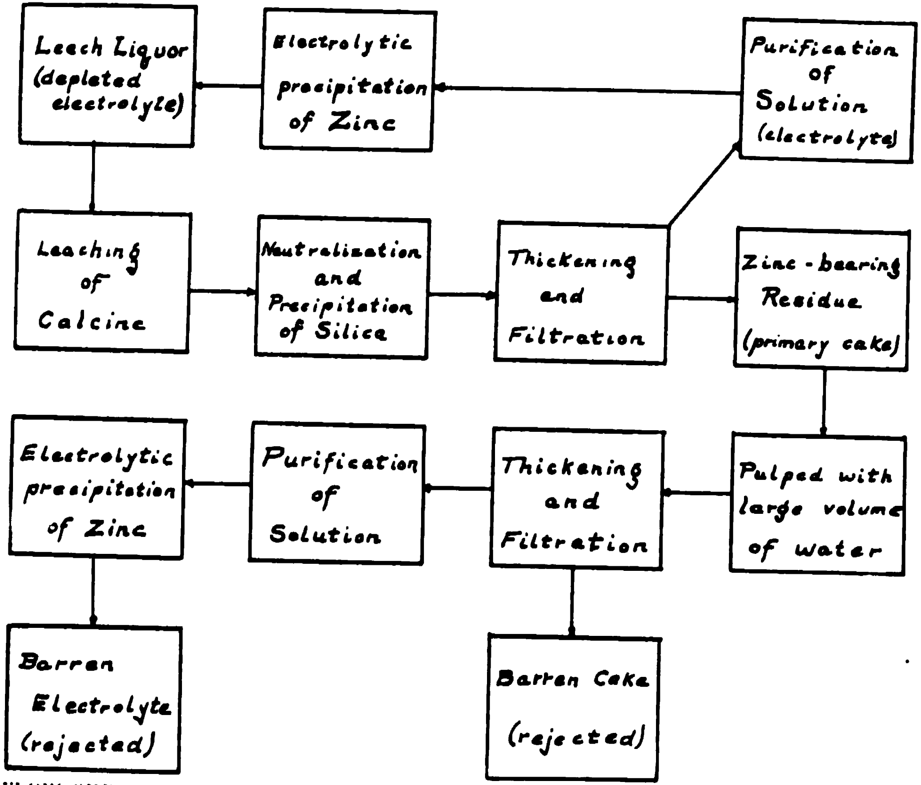
1907 1,255,437. Electrodeposition of metals.—**Frederick Laist** and **James Orr Elton,** Anaconda, Mont., assignors to Anaconda Copper Mining Company. Filed June 16, 1916. Issued Feb. 5, 1918.

In the deposition of metals by electrolysis, the combination with a purifying system, a storage system, and a main electrolytic system, of an indicator cell in the line of flow of the solution between the purifying and storage systems. 2 claims.

1908 1,255,438. Process of treating zinc ores.—**Frederick Laist,** Anaconda, Mont., assignor to Anaconda Copper Mining Company. Filed July 10, 1916. Issued Feb. 5, 1918.

The process of treating zinc ores containing iron, which consists in calcining the ore, leaching the calcine with a solution containing sulphuric acid, precipitating the iron from the resulting solution by a material containing zinc oxide, separating the precipitate from the iron-free solution, furnacing said precipitate at a temperature materially below that of the calcination, said temperature sufficient to render the ferric compounds insoluble, while avoiding substantial decomposition of zinc sulphate, and extracting the zinc sulphate from the furnaced product. 2 claims.

1909 1,255,439. Process of recovering zinc from ores.—**Frederick Laist** and **James Orr Elton,** Anaconda, Mont., assignors


Leach Liquor (depleted electrolyte)
Electrolytic precipitation of Zinc
Purification of Solution (electrolyte)
Leaching of Calcine
Neutralization and Precipitation of Silica
Thickening and Filtration
Zinc-bearing Residue (primary cake)
Electrolytic precipitation of Zinc
Purification of Solution
Thickening and Filtration
Pulped with large volume of water
Barren Electrolyte (rejected)
Barren Cake (rejected)

FLOW SHEET OF LAIST'S (ANACONDA) PROCESS OF TREATING SILICIOUS CALCINES
(See item 1913a)

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to Anaconda Copper Mining Company. Filed July 10, 1916. Issued Feb. 5, 1918.

The process of recovering zinc from its ores, which consists in leaching the ore with an acid solvent for zinc, precipitating iron as a ferric compound, treating the resulting solution with finely divided zinc to precipitate metals electronegative thereto, electrodepositing zinc in sponge form from portions of the treated solution, thereby further purifying such portions of the solution and preparing finely divided zinc for use in the precipitating stage of the operation, depositing further quantities of zinc as a reguline metal and re-using the resulting acid solution in the leaching process. 3 claims.

—Described in Met. & Chem. Eng., vol. 18, p. 549-50. May 15. 1918.

1910 1,255,440. Process of treating complex ores or concentrates therefrom.—**Frederick Laist,** Anaconda, Mont., assignor to Anaconda Copper Mining Company. Filed Nov. 3, 1916. Issued Feb. 5, 1918.

The process of recovering zinc, lead, copper and the precious metals from ores or concentrates containing the same, which consists in leaching the roasted ore with dilute sulphuric acid, separating and purifying the resulting zinc-bearing solution and recovering the zinc therefrom by electrolysis; smelting the residue containing the copper, the lead and the precious metals and some zinc, and thereby producing a matte containing the copper and precious metals and a fume consisting largely of oxides of lead and zinc; extracting the zinc from the fume by dilute sulphuric acid, leaving a residue high in lead; and recovering copper and the precious metals from the matte.

—Described in Min. & Sci. Press, vol. 116, p. 824. June 15, 1918.

1911 1,259,594. Treatment of zinc-bearing material containing iron.—**Anson G. Betts,** Ashville, N. C. Filed April 21, 1916. Issued March 19, 1918.

The process of treating oxidized zinc-bearing material containing iron, comprising leaching the material with an acid solution to dissolve out the greater portion of the zinc with a minimum of iron; leaching the residue with an acid solution for extraction of the remaining zinc, whereby more or less iron is also extracted and electrolytically recovering zinc from both solutions separately. 7 claims.

1912 1,262,190. Treatment of zinciferous ores.—**James H. Gillies** and **Percy M. Gillies,** East Camberwell, Victoria, Australia. Filed Jan. 22, 1917. Issued April 19, 1918.

In the treatment of complex sulphide ores of the kind indicated, fuming the zinc and the lead from the crushed and semi-roasted ore in a furnace, retreating the clinker with fluxes to recover precious metals and copper, and fuming off any remaining zinc, treating the zinc and lead fume with sulphuric acid solution to dissolve the zinc oxide and the resulting zinc sulphate solution with hydrogen sulphide gas to precipitate arsenical and like impurities and electrolyzing the purified solution to deposit metallic zinc.

1913 1,263,852. Method of purifying zinc-sulphate solutions.—**Russell B. Caples,** Great Falls, and **Frederick F. Frick,** Anaconda, Mont., assignors to Anaconda Copper Mining Company. Filed Sept. 4, 1917. Issued April 23, 1918.

In the purification of zinc sulphate solutions, the steps which consist in preparing a solution containing at least one part by weight of copper for each part by weight of arsenic and antimony to be eliminated, calculated as trioxides, and subjecting the said solution at a temperature of about 80° C. to the action of metallic zinc, whereby arsenic and antimony are precipitated in association with copper.

1913a 1,281,032. Process of recovering zinc.—**Frederick Laist,** Anaconda, Mont., assignor to Anaconda Copper Mining Company. Filed Jan. 29, 1918. Issued Oct. 8, 1918.

In a process of recovering zinc from a salicious calcine, the steps which comprise leaching the calcine with an acid liquor, neutralizing the liquor and thereby precipitating silica in presence of the insoluble residue, separating the zinc bearing solution from the residue, re-pulping the residue with water and separating the resulting dilute zinc-bearing solution therefrom, and separately recovering zinc from the two zinc-bearing solutions by electrolyzing said solutions with insoluble anodes. See also item 608a.

1913b 1,283,077. Electrolytic production of zinc.—**Galen Howell Clevenger,** Palo Alto, Cal., assignor to Herbert W. Gepp, Melbourne, Victoria, Australia. Filed May 7, 1917. Issued October 29, 1918.

In the electrodeposition of zinc, the method of removing cobalt from zinc sulphate electrolytes containing manganese, which comprises neutralizing the electrolyte and then precipitating the cobalt by means of an oxidizing agent. 10 claims.

1913c 1,283,078. Electrolytic recovery of zinc.—**Galen Howell Clevenger,** Palo Alto, Cal., assignor to Herbert W. Gepp, Melbourne, Victoria, Austrila. Filed May 7, 1917. Issued October 29, 1918.

In the electro-deposition of zinc, the method of removing cobalt from the electrolyte, which comprises precipitating the cobalt with nitroso-betanapthol by effecting the formation of nitroso-betanapthol within the electrolyte and precipitating the cobalt therewith. 10 claims. Patented also in England, No 115,847 of 1918.

Great Britain

1914 12,249 of 1886. Electrolytically obtaining metallic zinc from alkaline solutions of zinc oxide.—**W. S. Squire** and **S. C. C. Currie,** London.

"The solution is electrolyzed with an anode of iron or carbon and a cathode of mercury. The resulting amalgam is distilled to separate the mercury."

1915 12,630 of 1886. Obtaining metallic zinc from its ores.—**W. S. Squires** and **S. C. C. Currie**, London.

"The ore is dressed, obtained as oxide by roasting, dissolved in potassium or sodium hydroxide, and electrolyzed with a mercury cathode." Modification of 12,249, above.

1916 6,294 of 1887. Improvements in the electrolytic treatment of zinc and its ores.—**A. Watt**, London.

Uses as electrolyte a "dilute vegetable acid, preferably commercial acetic acid, or a solution of zinc or its ores in such a liquid. The anodes may be masses of impure zinc or may be of carbon or other insoluble material. The cathodes may be of carbon, greased or dirty metal, or thin sheets of good zinc. An excess of metallic impurities in the solution may be precipitated by sulphuretted hydrogen."—J. S. C. I.

1917 9,886 of 1888. Improvements in the reduction of zinc oxides. —**C. A. Burghardt**, Manchester, England.

Electrolyzes an alkaline zincate solution with pure zinc cathodes.

1918 17,205 of 1889. Improvements in the process of obtaining zinc by electrolysis.—**A. S. Elmore**, Rothwell, England.

Porous cells are placed in a bath of zinc sulphate. The anode is of iron. The cathode is a disc or cylinder which revolves, and as the zinc is deposited upon it, it is acted on by a burnisher, which makes the deposited metal compact and close in texture.

1919 8,716 of 1890. New or improved process for obtaining, by electrical decomposition, metallic zinc from solution of sulphite of zinc.—**E. Edwards**, London.

"Sulphite is used instead of sulphate as electrolyte, as the difficulty of keeping the bath neutral is thereby obviated and the metal obtained of better quality."

1920 2,225 of 1892. Improvements in the method of purifying electrolytes containing zinc, relating to or connected with the electrometallurgy of zinc.—**G. Nahnsen**, Cologne, Germany.

Zinc powder is used. "When the impurities consist of copper only the amount of 1%, 10 lbs. of copper must be precipitated by means of zinc powder in the daily production of 1000 lbs. of zinc, which will necessitate a daily addition of 11 lbs. of zinc."

1921 2,913 of 1892. Improvements in the electrometallurgic extraction of zinc.—**G. Nahnsen**, Cologne, Germany.

"Uses an electrolyte composed of a mixture of the sulphate of zinc with a sulphate of the alkalies, but preferably not magnesia, and heating the bath to a temperature of about 130° F." Claims higher conductivity than zinc sulphate electrolyte, and wide range of current density is possible.

1922 16,892 of 1892. Process and apparatus for the extraction, separation, and refining of metals by electrolysis.—**D. Tommasi**, Paris.

1923 13,336 of 1893. Electrolytic recovery of nickel, zinc or other metals.—**Carl Hoepfner.**

1924 17,446 of 1893. Production of zinc by electrolysis.—**W. Wright,** Bettws-y-coed, and **J. B. Hammond,** Bromley.

Pressing the spongy zinc into thin sheets before melting, so that no oxide is produced in melting.

1925 5,537 of 1894. Electrolytic precipitation of zinc and alloys of zinc, and apparatus therefor.—**R. Heathfield** and **W. S. Rawson,** London.

Deposition on iron, steel, or other metallic articles, which are first electrolytically coated with mercury, and then treated electrolytically in a zinc-salt solution.

1926 7,145 of 1894. Improvements in or connected with the electrodeposition of zinc or zinc compounds, and the treatment of the deposited metal or compounds.—**S. O. Cowper-Coles** and **B. W. Walker,** London.

Claims use of an alkaline electrolyte in which zinc or a zinc compound, finely divided, is suspended; also the alternation of brief currents of high density with longer currents of lower density, to brighten the deposited metal; also the use of a sort of sand blast to brighten the metal after deposition.

1927 8,085 of 1894. Improvements in the art of producing metallic zinc.—**P. C. Choate,** New York.

"Zinc is volatilized as fume... This fume is reheated with carbon at moderate temperature so as to eliminate any metallic constituents which are more volatile than zinc. It is finally reduced, distilled, and cast into anodes. These anodes are immersed in a zinc sulphate solution containing a little soluble chloride... On passing a current of electricity, pure zinc is deposited."—J. S. C. I.

1928 22,826 of 1894. Preparation of zinc solutions for electrolysis.—**J. Brock, A. E. Waring** and **F. Hurter,** Liverpool, England.

"Zinc chloride solutions which have been obtained by roasting ore and dissolving the roasted product in HCl, may be freed of sulphuric acid by adding calcium, barium, or strontium chloride, and filtering."—Zeits. f. Elektrochem.

1929 22,827 of 1894. Preparation of zinc solutions for electrolysis.—**J. Brock, A. E. Waring** and **F. Hurter,** Liverpool, England.

If the solution contains oxides of other metals, zinc oxide is added at high temperature, thus precipitating the metals detrimental to electrolysis.

1930 22,828 of 1894. Utilization of zinc blende for obtaining metallic zinc and sulphur, effecting the decomposition of common salt for the production of soda and chlorine.—**J. Brock, A. E. Waring** and **F. Hurter,** Liverpool, England.

Zinc blende is roasted to obtain zinc oxide and sulphurous acid, and from the latter sulphuric acid is obtained. The zinc oxide is converted into zinc chloride and electrolyzed.

1931 24,861 of 1894. Improvements in the treatment of sulphide ores containing zinc in association with other metals.—**T. Parker,** Wolverhampton, England.

Treatment of zinc-lead sulphides by dissolving in hydrochloric or sulphuric acid, electrolyzing the solution for zinc, and recovering the acid, and treating the residues for silver and lead.

1932 584 of 1895. Improved method and apparatus for obtaining chlorine and zinc in the treatment of ores containing zinc or blende and other metals or metalloids.—**H. R. Lewis,** London, and **C. Gelstharp,** Manchester.

—Described in Jour., Soc. Chem. Ind., vol. 15, p. 119. Feb. 29, 1896.

1933 2,999 of 1895. Improvements in and means to be employed for the obtaining of zinc from its ores, and electrolytic deposition of zinc upon iron or other metal or alloys.—**S. O. Cowper-Coles,** London.

"Bright, non-spongy deposits are obtained from the following electrolyte: a gallon of water, 35 ounces zinc sulphate, 12 ounces iron (preferably ferric) sulphate. The electrolytic oxygen, liberated when the zinc is deposited, prevents the formation of hydrogen compounds of zinc, and consequently of spongy zinc.

1934 4,154 of 1895. Improvements in apparatus for use in electrolysis.—**S. O. Cowper-Coles,** London.

"The anodes and the articles to be coated make contact with conducting cross- or bridge-pieces, 'girders,' superposed but insulated from each other. The object is to bring the anodes and the articles to be coated into close proximity in a simple and convenient manner."—J. S. C. I.

1935 8,449 of 1895. Leaching and electrolytic recovery of zinc.—**C. Hoepfner.** April 29, 1895.

"Roasts and dissolves zinc oxide with H_2SO_3, neutralizes excess of acid, decomposes $ZnSO_3$ with $CaCl_2$, obtaining $ZnCl_2$ in solution, and $CaSO_3$ precipitated; the latter is soluble in H_2SO_3 and is available for wood-pulp manufacture. Zinc is precipitated by electrolysis from the chloride solution." Mineral Industry, 1896.

1936 13,434 of 1895. Electrolytic deposition of zinc.—**Siemens and Halske,** Berlin.

Keeps up a vigorous circulation of the electrolyte by means of jets of compressed air, so as to prevent the formation of spongy zinc.

1937 13,534 of 1895. Electrolytic treatment of refractory zinc-lead ores.—**E. A. Ashcroft,** Broken Hill, New South Wales.

Modifications of patentee's process. See also 7532 of 1897, below.

1938 14,783 of 1895. Improved process for the treatment of metalliferous ores and products.—**E. A. Ashcroft,** Grays, England.

An improvement on 13,534, above. Employs anodes composed of iron or copper mattes.

1939 17,745 of 1895. Improvements in electrolytic or galvanic processes or cells.—**C. Hoepfner,** Giessen, Germany, and **H. H. Lake,** London.

"To allow the use of as low an E. M. F. as possible, soluble anodes are employed." These may consist of lead or similar metals, but not of zinc or iron.

1940 19,934 of 1895. Process and apparatus for the electrolytic production of metallic zinc and metallic copper from zinc ores containing copper, obtaining oxygen gas as a by-product.—**C. A. Burghardt,** Manchester, and **G. Rigg,** Eccles, England.

—Described in Mineral Industry, vol. 5, p. 602. 1896.

1941 22,732 of 1895. Improvements in a process and apparatus for the electrolytic production of metallic zinc from ores of zinc, and the production of oxygen gas.—**C. A. Burghardt,** Manchester, and **G. Rigg,** Eccles, England.

Modification of 19,934, above.

1942 23,543 of 1895. Improved process for treating sulphide ores containing zinc and other metals.—**T. Parker,** Wolverhampton, England.

Treats zinc ores with hot hydrochloric acid and keeps the solution neutral with carbonate of zinc, then electrolyzes to produce zinc and chlorine.

1943 25,002 of 1895. Improvements in electrolytic apparatus.—**R. Heathfield** and **W. S. Rawson,** London.

Rotating deposition barrel with Portland cement staves.

1944 1,575 of 1896. Process for the electrolytic extraction of zinc from its ores.—**Siemens** and **Halske,** Berlin.

"Zinc oxide is dissolved in neutral aluminum sulphate, electrolyzed between insoluble anodes at 3 volts pressure, whereby zinc is deposited at the cathode, and oxygen at the anode, while the basic aluminum sulphate is reconverted to neutral sulphate for subsequent use. The bath is best prepared by dissolving the ZnO in a warm 10 to 15% solution of neutral aluminum sulphate."—Mineral Industry, 1896.

1945 4,432 of 1896. Process for the recovery of zinc from blende ores.—**The Exploring and Gold Mining Association, Ltd.,** and **S. H. Emmons,** California.

The roasted ore is placed in a series of vats arranged in cascade form, each slightly lower than that preceding it. The alternate vats are connected with an electrolyzing current. Water flowing over the ore in vat no. 1 extracts zinc sulphate, which is electrolyzed in vat no. 2. The sulphuric acid liberated is neutralized by the zinc oxide in vat no. 3, and is ready to be electrolyzed again in vat no. 4, and so on. See also item 1708.

1946 11,074 of 1896. Method of producing zinc by electrolysis.—**E. A. Ashcroft,** Melbourne, Victoria.

1947 11,076 of 1896. Improvements in the treatment of ores containing zinc.—**E. A. Ashcroft,** Melbourne, Victoria.

"This process was devised to enable zinc blende (alone or mixed with galena) to be so treated as to yield directly an electrolyte from which the zinc may be deposited electrolytically without formation of spongy deposits. This may be accomplished by having oxy salts of zinc in the solution from which the zinc is being separated."

—Described in Jour. Soc. Chem. Ind., vol. 16, p. 684. Aug. 31, 1897.

1948 13,169 of 1896. Treatment of sulphide ores for the separation of zinc from the lead and other metals.—**H. Mohr,** Hampstead.

"The pulverised ore is fused with acid sodium or potassium sulphate, and the fused mass is dissolved in hot water, a small quantity of sulphuric acid being added when necessary." Zinc is deposited by electrolysis.—J. S. C. I.

1949 17,608 of 1896. Improvements in means or apparatus for effecting the electro-deposition of zinc upon tubes or other circular or analogous objects.—**S. O. Cowper-Coles,** London.

1950 24,573 of 1896. Production of zinc chloride, or of zinc and chlorine.—**E. Hoepfner,** London.

—Described in Jour. Soc. Chem. Ind., vol. 16, p. 1015. Dec. 31, 1897.

1951 25,804 of 1896. Improvements in the electrolytic production of zinc and alkalies.—**Otto Dieffenbach,** Darmstadt.

1952 7,532 of 1897. Improvements in the combined electrolytic and leaching treatment of zinc bearing ores and zinc-bearing products.—**E. A. Ashcroft,** Newcastle, N. S. W.

An improvement on 13,534 of 1895 above. "Employs carbon instead of soluble iron anodes; and the solution of ferric sulphate or chloride employed in leaching the zinc ores is not prepared electrically, but is only regenerated in the anode compartments."

—Described in Jour. Soc. Chem. Ind., vol. 17, p. 253. March 31, 1898.

1953 4,296 of 1898. Improved process for the recovery of zinc from refractory zinc-bearing ores.—**J. Jones,** Melbourne, Australia.

Electrolysis of zinc sulphate and ammonium sulphate solution. See also item 1710.

1954 5,943 of 1898. Improvements in the treatment of zinc-bearing ores for obtaining zinc and other metals therefrom.—**S. O. Cowper-Coles,** London.

—Described in Jour. Soc. Chem. Ind., vol. 17, p. 1053, Nov. 30, 1898.

1955 22,710 of 1899. Apparatus for the electrolytic extraction of zinc.—**S. Stepanoff,** Petrograd, Russia.

A method of increasing the extraction of zinc electrolytically from the sulphate.

1956 24,135 of 1899. Process for extracting zinc from sulphide ores.—**James Gitsham,** Victoria, Australia.

"The pulverized ores are roasted at a temperature of about 600°F., with the addition of 1% of powdered metallic zinc; they are then leached, at first with water, afterwards with dilute sulphuric acid, aided by steam; finally the zinc is precipitated by an alkali."—J. S. C. I.

1957 9,563 of 1900. An electrolyzing process for zinc and other salts with insoluble anodes.—**Societe des Piles Electriques,** Paris.

Improved circulation of fluids in cells for electro-deposition of zinc.

—Described in Jour. Soc. Chem. Ind., vol. 20, p. 484. May 31, 1901.

1958 17,612 of 1900. Treatment of sulphide ores.—**J. Swinburne** and **E. A. Ashcroft,** London.

Method of purifying the bath.

1959 22,699 of 1900. Electrolytic separation of metals.—**H. A. Frasch,** Hamilton, Ontario, Canada.

Improved electrolytes for use in electrolytic separation of metals.

1960 23,647 of 1900. Electrolytic deposition of metals.—**H. C. Harrison** and **J. Day,** London.

Apparatus for the rapid electro-deposition of metals with a current of high density and producing tough metal, the electrolyte being projected tangentially on the surface of deposit.

1961 1,849 of 1901. Electrolytic treatment of alkali metals.—**A. Brochet** and **G. Ranson,** Paris, France.

Electrolyzing sulphides of alkali earth metals in the presence of a chloride, thus producing hydrated oxides.

1962 9,731 of 1901. Electro-deposition of metals.—**S. O. Cowper-Coles**, London.

Improvements in inventor's system of electro-deposition on rapidly rotating mandrels, by projecting the electrolyte tangentially against the mandrels.

1963 15,128 of 1902. Electro-deposition of zinc.—**Columbus Electricity Company**, Ludwigshafen-on-Rhine, Germany.

In the electrodeposition of zinc on sheet metal, improved method for keeping the anode and cathode at equal distance and of reducing the distance in order to decrease the resistance.

1964 2, 574 of 1903. Electrolytic extraction of metals.—**Mechwart, Coltri & Co.**, Milan, Italy.

In an electrolytic cell for the extraction of metals from roasted sulphides, the use of a liquid diaphragm between the anode and cathode cells and the use of a heated anode.

1965 15,420 of 1903. Obtaining zinc by electrolysis.—**Karl Kaiser**, Berlin, Germany.

"The ore, after roasting and crushing, is treated with sufficient zinc chloride to agglomerate the mass, forming oxy-chloride of zinc. After drying, the mass is crushed and treated with hydrochloric acid preferably while hot. In a quarter of an hour the whole of the zinc present should have dissolved, with, however, but little of the iron contained in the mineral. Electrolysis is then effected with insoluble anodes and zinc, iron or other cathodes. The anodes may, with advantage, be made cylindrical and be rotated on their axes."—J. S. C. I.

1966 24,985 of 1906. Electrolytic refining.—**S. O. Cowper-Coles**, London.

"In the electrolytic refining of metals, the arrangement of three electrodes concentrically, the inner and outer being the cathode and the middle one the anode, and the whole rotated at a high speed."—E. & M. J.

1967 8,562 of 1907. Electro-deposition of zinc.—**H. Paweck**, Vienna.

"Zinc is deposited electrolytically from a bath containing one or more salts of the metal, with or without the addition of conductive salts or other substances. The liquid is maintained neutral, or preferably slightly acid, by intermittent and continuous regeneration... The latter is effected by addition of substances which yield hydrogen ions in aqueous solution. Boric or phosphoric acid or the like may also be added....."—J. S. C. I.

1968 24,631 of 1909. Process for utilizing spongy zinc obtained electrolytically.—**Eduardo Sanna**, Ingurtosu, Italy.

"The spongy zinc is washed in a solution of sodium nitrate, and then while still moist is heated to 100°-150°C. and simultaneously exposed to a pressure of about 1000 kilos per sq. cm. It is stated that dense metallic zinc is readily obtained in this way."—J. S. C. I. Patented also in France, no. 415,639; in Germany, no. 217,632.

—Described in Min. Mag., vol. 3, p. 58. July, 1910.

1969 1,341 of 1910. Recovery of metals in complex or low grade ores.—**S. Laszczynski,** Miedzianka, Poland and **W. Stoeger,** Vienna. Jan. 8, 1910.

Copper and zinc are deposited in separate operations.

—Described in Jour. Soc. Chem. Ind., vol. 30, p. 429-30. April 15, 1911.

1970 17,785 of 1910. Treatment of silicious zinc ores.—**F. B. Dick,** Hampton, Middlesex, England.

The finely divided ore is mixed with water, and sulphuric acid is added, not in excess, to convert zinc into sulphates. After evaporation, the mass is heated to render the hydrated silica insoluble but not to decompose the zinc sulphate. The residue is leached with water and electrolyzed for zinc.

1971 15,128 of 1911. Manufacture of manganese peroxide anodes. —**Siemens** and **Halske Akt.—Ges.**

1972 11,271 of 1912. Electro-deposition of zinc.—**E. Ballegeer,** Uccle-lez-Brussels, Belgium. May 11, 1912

"The article, after being cleaned, is dipped into a bath of water (100 litres), a zinc chloride solution of 46° Be. (40 litres), ammonium chloride (8 kilos), sodium chloride (2½ kilos), and tartaric acid (2½ kilos). An electric current is passed through the cold bath, using a pure zinc plate as anode, and employing a current density of 100 amp. per sq. m. of cathode surface."—J. S. C. I.

1973 4,861 of 1915. Apparatus for electrolytic production of zinc. —M. Perreur-Lloyd, Boulogne, France. Patented also in France, No. 472,764.

1974 9,957 of 1915. Preparation of electrolytes for use in the electric deposition of metals.—**P. Marino,** London.

"An electrolyte, for the electrodeposition of copper, zinc, lead, etc., is prepared by treating a solution of a salt, or oxide of the metal, with a suitable reagent, and then completely dissolving the precipitate in a suitable solvent. Ammonium, sodium, or potassium salicilate and ammonia are then added to the solution thus prepared."—J. S. C. I.

1975 10,133 of 1915. Process for electrolytic deposition on all metals of aluminum, tin, nickel, copper, zinc, iron, steel, or alloys thereof.—**P. Marino,** London.

"An electrolyte for plating is prepared by using one of the metals named as anode in a strong solution of $Na_4P_2O_7$ to which has been added H_3PO_4, say 10%, and sulphanilic acid, say 5 to 15 %. A soluble anode is also used during plating."—Chem. Abst.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 54, Jan. 15. 1916.

1976 16,336 of 1915. Electrodeposition and extraction of zinc.—**U. C. Tainton,** London, and **J. N. Pring,** Chester.

"A strongly acid zinc solution, containing no colloid, is electrolyzed with high current density. The zinc deposited is firm, though lacking in smoothness. 16% of H_2SO_4 may be added to a saturated solution of $ZnSO_4$ to form the electrolyte. A current density of 600 amp. per square foot may then be employed. The anodes may be of zinc, lead or lead oxide. The invention may be employed in the extraction of zinc from its ores, as by the cyclic process."--Chem. Abst.

—Described in Jour. Soc. Chem. Ind., vol. 36 p. 37. Jan. 15, 1917.

1977 4,681 of 1916. Apparatus for the electrolytic production of zinc.—**M. Lloyd-Perreur.**

—Described in Min. Jour., vol. 112, p. 156. March 4, 1916.

1978 100,739 of 1916. Electrolytic apparatus.—**Siemens and Halske, A.—G.,** Berlin.

The wires forming the electrodes are connected with and are hung freely from the same conductor and are weighted at their lower ends with a single piece, or with individual spherical, cylindrical or other weighting pieces; or the wires may be weighted at both ends and hung over the conductor or an insulator.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 931. Sept. 15, 1916.

1979 104,697 of 1916. Extraction of zinc.—**H. L. Sulman, H. F. K. Picard,** and **The Metals Extraction Corporation, Ltd.,** London.

Electrolysis of sulphate solution.

1980 105,255 of 1916. Electrolytic deposition of zinc on metallic surfaces.—**P. Marino,** London.

"The electrolyte consists of a concentrated aqueous solution of a zinc salt, to which 8 to 10% of glycero-sulphuric acid, 8 to 10% of boric acid, and 5 to 10% of a halogen derivative of lactic acid has been added."—J. S. C. I.

1980a 105,830 of 1916. Electrolytic production of sulphides.—**C. O. Griffith.**

"Sulphides of zinc, antimony, iron, lead, copper, etc., are prepared by the use of electrodes both of the same metal, the cathode being coated wholly or in part with sulphur. A suitable electrolyte contains chloride of NH_4 or Na of the electrode metal, or a mixture. The temperature of the electrolyte may be 50° to 70°."—Chem. Abst.

1980b 108,312. Refining metallic zinc-bearing materials by the electrolytic process.—**C. H. Aldrich** and **J. K. Bryan,** assignors to The Electrolytic Zinc Co., New York. Appl. No. 10,073 of 1917.

"Zinc-bearing minerals are refined electrolytically by use of an acid electrolyte containing from 0.1 to 0.5% of free acid, at about 40°C, or lower."

—Described in Jour. Soc. Chem. Ind., vol. 37, p. 518A. Sept. 16, 1918.

1981 112,336 of 1917. Treatment of zinciferous ores.—**J. H. and P. M. Gillies,** East Camberwell, Victoria. Feb. 1, 1912.

A purified zinc sulphate solution is electrolysed with zinc cathodes and lead anodes. To secure an even deposition, .5 to 1 gram of gum arabic may be added per litre of solution.

—Described in Jour. Soc. Chem. Ind., vol. 37, p. 94A-95A.

France

1982 358,622. New process for electrodeposition of zinc and its alloys.—**G. Langbein & Co.** Oct. 18, 1905.

"The process of electrodeposition of zinc upon metallic objects is improved by the addition of urea to the bath. Double salts which are readily soluble are formed, and a high current density can be maintained without resulting in the formation of a spongy deposit."—J. S. C. I.

1983 370,803. Electrolytic extraction of zinc from its ores.—**C. J. Tossizza.** Dec. 30, 1905.

"Salts of zinc are electrolyzed, using insoluble anodes, in a vat divided into two compartments by a porous diaphragm. The solution in the anode compartment is saturated with sulphurous acid to act as a polarizer, in order to permit electrolysis to be carried on with a low and constant voltage. Around the cathode is maintained a liquid charged with substances which will neutralize the free sulphuric acid produced at the anodes. Evolution of hydrogen at the cathode is thus avoided, and good deposits of zinc are obtained."—J. S. C. I. See also U. S. Patent 703,857.

1984 406,150. Process for the preparation of zinc compounds (oxide, etc.) by electrolysis.—**E. Leriche.** Dec. 1, 1908.

"Consists in electrolyzing, with a zinc anode and without a diaphragm, a solution containing a salt of a soluble base, the acid radical of which forms a soluble salt with zinc..."

—Described in Jour. Soc. Chem. Ind., vol. 29, p. 425. April 15, 1910.

1985 415,639. Extraction of lead and zinc from mixed ores.—**Edoardo Sanna,** Ingurtosu, Italy. May 6, 1910.

The ore is treated with a boiling solution of caustic soda and electrolyzed in an iron vessel. The lead is separated in a spongy condition. The residual solution is again electrolyzed in a zinc vat. A coherent deposit is obtained by the means described in English Patent 24,631 of 1909.

1986 476,346. Cyclic process for the treatment of complex, manganiferous ores of zinc and lead.—**A. G. French.** Oct. 20, 1914.

The ore is roasted at a low temperature (About 700° C.) until evolution of sulphur dioxide ceases, then mixed with 4 to 5% of sodium bisulphate, and the mixture ground with water and leached. The solution, containing zinc, manganese, and sodium sulphates, is electrolyzed between anodes of lead and cathodes of zinc foil, manganese dioxide being deposited on the former, and pure zinc on the latter. A current of 300 amp. per sq. m. of cathode surface is employed at 2½ to 4¼ volts.

—Described in Jour. Soc. Chem. Ind., vol. 35, p. 54. Jan. 15, 1916.

1986a 481,816. Electrolytic separation of zinc from solution.—**Compagnie Bordelaise des Produits Chimiques.** Jan. 23, 1917.

An iron anode is used, and the cathode is not separated by a diaphragm.

1986b 481,832. Apparatus for extracting zinc from its minerals.—**L. Sturbelle.** Jan. 23, 1917.

"The construction of the apparatus is such, with respect to the disposition of the elements constituting the anode around the cathode, as to secure a uniform distribution of the current upon the cathode."—Chem. Abst.

Germany

1987 75,556. Anode of basic zinc salt.—**Hoeflich.** 1894.

—Described in Zeits. f. Elektrochem., vol. 1, pp. 138-39. July 15, 1894.

1988 84,579. Electrolytic recovery of zinc and chlorine from sulphide ores, roasted pyrites or other residues.—**E. Matthes** and **Weber.** Jan. 19, 1895.

1989 118,291. Electrolytic recovery of zinc from zinc ores and zinciferous residues.—**Julius Nothmann,** Kattowitz, Silesia. Oct 1898.

See also item 1646.

—Described, with diagr., in Zeits. f. angewandte Chem., vol. 14, pp. 346-47. April 2, 1901.

1990 118,676. Electrolytic recovery of zinc and other metals, using soluble metallic anodes.—**Societe des Piles Electriques,** Paris. Nov., 1899.

—Described with diagr., in Zeits. f. angewandte Chem., vol. 14, p. 347. April 2, 1901.

1991 151,336. Process for the production of zinc or zinciferous precipitates by electrolysis.—**Emmanuel Goldberg,** 'Moscow, Russia. Feb. 13, 1902.

See also item 1696.

—Abstract. Zeits. f. angewandte Chem., vol. 17, p. 1216. Aug. 19, 1904.

1992 162,785. Process for the electrolytic recovery of zinc from sulphate solutions.—**Siemens** and **Halske.** Nov. 21, 1903.

Uses an anode of platinum or platinum alloy.

—Described in Zeits. f. Electrochem., vol. 12, p. 74 Jan. 26, 1906.

—Described in Zeits. f. angewandte Chem., vol. 18, p. 1865. Nov. 24, 1905.

1993 184,516. Process and apparatus for the electrolytic separation of zinc, magnesium and other metals, using mercury cathodes.—**Decker Mfg. Co.,** Wilmington, U. S. A.

1994 195,033. Process for the electrolytic recovery of metallic zinc in compact form by electrolyzing a solution of zinc sulphate without the use of a diaphragm.—**Siemens and Halske,** Berlin. Aug. 30, 1906.

—Described in Zeits f. angewandte Chem., vol. 21, p. 990. May 15, 1908.

1995 213,004. Process for removing iron from zinc sulphate solutions to be used for the electrolytic separation of zinc, by means of peroxides and zinc oxide.—**Siemens and Halske,** Berlin. April 12, 1908.

"Manganese dioxide is used for the oxidation of the iron contained in zinc sulphate solutions, with a view to the subsequent precipitation of the iron with zinc oxide. The manganese dioxide is regenerated during the electrolytic separation of the zinc from the purified solution."—J. S. C. I.

—Described in Zeits. f. angewandte Chem., vol. 22, p. 2247. Nov. 12, 1909.

1996 233,252. Process for the electrolytic production of zinc from zinc pyrite cinders or other low-grade zinc-bearing raw materials, in which the raw material is leached out after a chloridizing roast.—**Siemens and Halske,** Berlin. Nov. 17, 1909.

—Described in Zeits. f. angewandte Chem., vol. 24, p. 814. April 28, 1911.

1997 244,930. Process for the electrolytic separation of zinc, the electrolyte consisting of an aqueous solution of zinc fluoride, preferably in association with ammonium fluoride. —**Johann Matuschek,** Vienna, Austria. April 22, 1911.

See also item 1695.

—Described in Zeits. f. angewandte Chem., vol. 25, p. 983. May 10, 1912.

1998 267,531. Process for the recovery of zinc from ores, concentrates, residues, salts, or the like.—**Edgar A. Ashcroft,** Sogn, Norway. April 21, 1912.

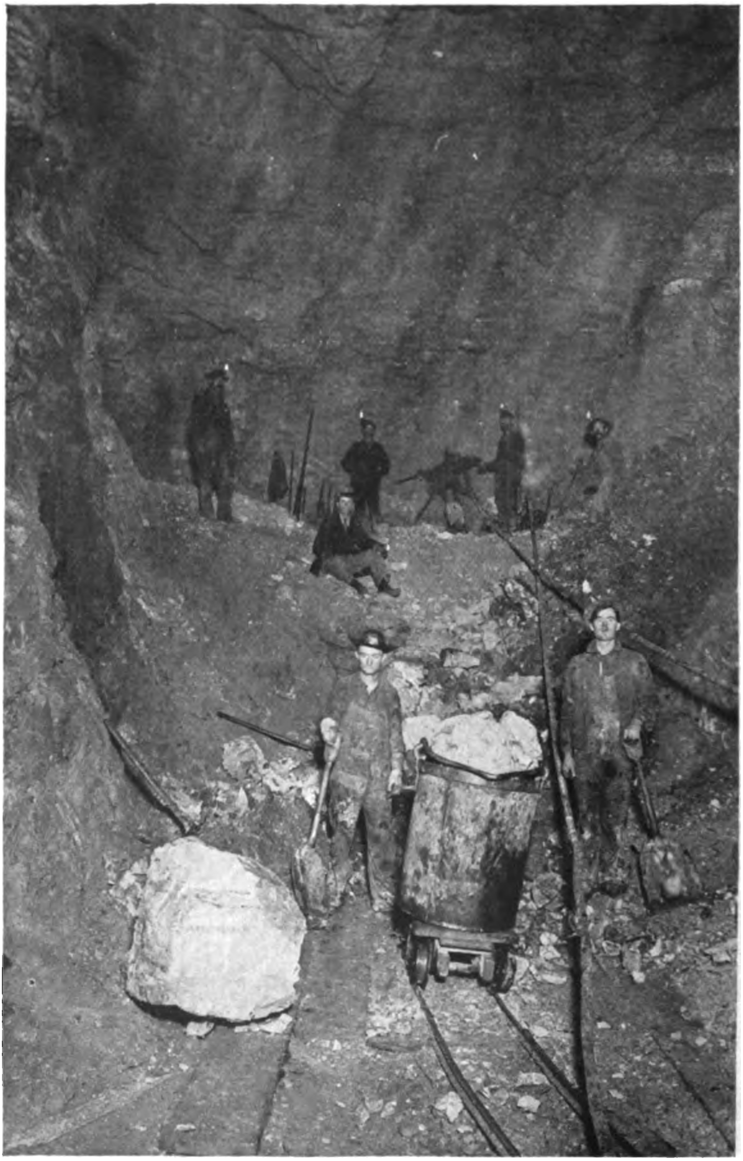
Electrolysis of chloride solution.

—Described in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 42. Jan. 16, 1914.

1999 277,359. Regulating the circulation of the electrolyte in the electrodeposition of zinc.—**H. K. Borchgrewink** and **R. Molstad,** Christiania, Norway. Feb. 20, 1913.
—Described, with diagr., in Zeits. f. angewandte Chem., vol. 27, pt. II, p. 588. Oct. 23, 1914.

2000 282,234. Process for making electrolytic zinc sponge compact.—**Griesheim-Elektron,** Griesheim, Germany. June 29, 1913.
See also item 1751.

2001 285,652. Electrolytic process for the recovery of metals, as copper, zinc or nickel, from materials which contain the metal partly as oxide and partly as sulphide.—**Noak V. Hybinette,** Christiansand, Norway. Nov. 8, 1912.
—Described in Zeits. f. angewandte Chem., vol. 28, pt. II, p. 434. Aug. 20, 1915.
See also item 1702.



UNDERGROUND IN A ZINC MINE
Missouri-Kansas-Oklahoma District

SPELTER

2002 Analysis of spelter. Eng. & Min. Jour., vol. 100, pp. 439-40. Sept. 11, 1915.

Abstract of report of committee of American Chemical Society.

2003 The behavior of heated zinc.—**James Scott.** illus. Metal Industry, vol. 4, pp. 138-39. 1912.

2004 Cadmium in spelter.—**W. R. Ingalls.** Eng. & Min. Jour., vol. 79, p. 697. April 13, 1905.

—Abstract. Zeits. f. angewandte Chem., vol. 18. p. 1462. Sept. 8, 1905.

2005 Cadmium in spelter.—**W. R. Ingalls.** Jour. Inst. Metals, vol. 16, pp. 196-99. 1916.

Deleterious effect of cadmium, especially in spelter destined for cartridge brass. Sampling of spelter.

—Abstract. Min. Jour., vol. 114, p. 659: Sept. 30, 1916.

—Abstract, with additional comments: Zinc and its common impurities. Min. Mag., vol. 15, pp. 239-40. Oct., 1916.

—Abstract. Jour. Soc. Chem. Ind., vol. 35, p. 1020. Oct. 16, 1916

2006 Cadmium in spelter. Eng. & Min. Jour., vol. 103, pp. 299-300. Feb. 17, 1917.

Discussion of paper by W. R. Ingalls, above.

2007 Chemical analysis of spelter.—**A. M. Fairlie.** Metal Industry, vol. 2, pp. 350-51. Oct., 1910.

Detailed description of the methods employed for the estimation of zinc and the common impurities in spelter.

—Abstract. Jour. Inst. Metals, vol. 5, pp. 331-32. 1911.

2008 Comparison of granulated and drilled samples of spelter.—**E. M. Johnson.** West. Chem. & Met., vol. 6, pp. 201-4. June, 1910.

Granulated sample shows slighter varieties in per cent of iron and lead than does drilled sample, and has other advantages.

2009 Grades and uses of spelter.—**G. C. Stone, W. H. Bassett** and **M. N. Price.** Iron Age, vol. 98, p. 86. July 13, 1916.

The common impurities—aluminum, iron, lead, cadmium; the amounts allowable in different grades, and their effects on the spelter's properties.

—Same. Min. Wld., vol. 45, pp. 287-88. Aug. 12, 1916.

—Same. Eng. & Min. Jour., vol. 102, pp. 331-32. Aug. 19, 1916.

—Abstract, with additional comments. Min. Mag., vol. 15. pp. 239-40. Oct., 1916.

2010 The kinds of spelter. Eng. & Min. Jour., vol. 99, pp. 292-93. Feb. 6, 1915.

—Correction., p. 460. March 6, 1915.

2011 Physical and chemical properties of zinc. Mineral Industry, vol. 12, pp. 363-66. 1903.

Reduction temperature, specific heat, atmospheric action, etc.

2012 Prime western spelter. Eng. & Min. Jour., vol. 86, p. 820. Oct. 24, 1908.

Editorial giving history of the term.

2013 The properties of spelter. Eng. & Min. Jour., vol. 94, p. 146. July 27, 1912.

Editorial: certain spelters of apparently equivalent composition give different results in practice.

2014 Sampling of spelter. Eng. & Min. Jour., vol. 102, p. 108. July 8, 1916.

Methods. See also next item.

2015 Sampling of spelter. Eng. & Min. Jour., vol. 102, p. 358. Aug. 19, 1916.

Grades and sampling methods, as affected by price fluctuations.

2016 Spelter for high grade brass; report of zinc producers to the Committee on Raw Materials of the War Industries Board. Metal Industry, vol. 16, pp. 175-76. April, 1918.

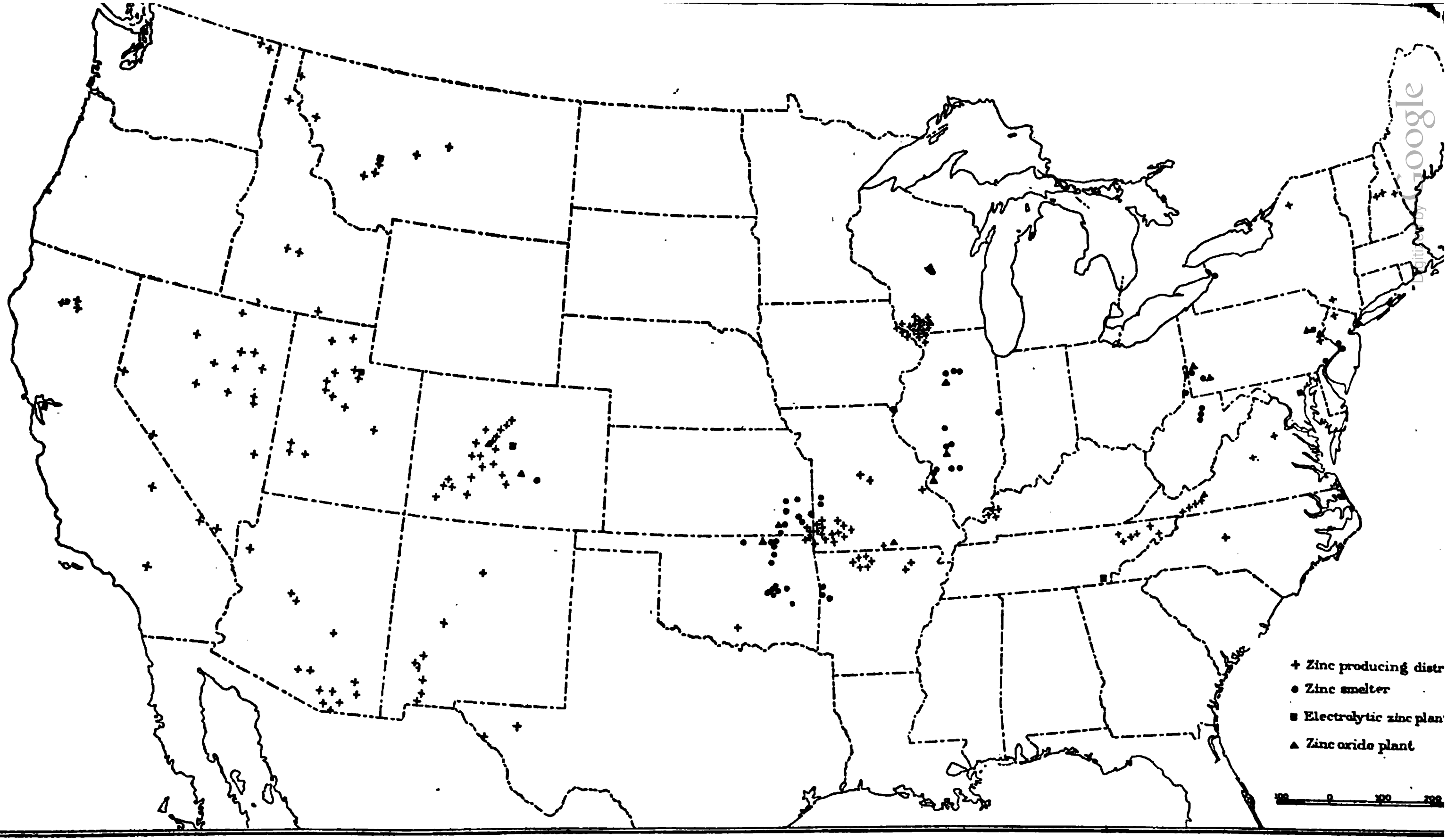
2017 Spelter manufacture and properties.—**George C. Stone.** Amer. Inst. Metals, Trans., vol. 8, pp. 174-95. 1914.

"Summary of the development of zinc metallurgy and review of the most representative zinc furnace designs." Discussion of impurities in spelter—iron, cadmium, arsenic, lead—their cause and effect.

—Same. Min. & Sci. Press, vol. 109, pp. 754-59. Nov. 14, 1914.

—Abstract. Met. & Chem. Eng., vol. 12, p. 643. Oct., 1914.

—Abstract, in German. Metall u. Erz, vol. 12, pp. 9-11. Jan. 8, 1915.



MAP SHOWING THE ZINC INDUSTRY OF THE UNITED STATES
As of January, 1919

ACTIVE ZINC SMELTERS IN THE UNITED STATES

(Includes plants working on ore alone, on ore and drosses, and on drosses alone.)

Operating company. (A—acid plant; not necessarily at the smelter.)	Location.	Retorts at close of 1915.	Retorts at close of 1916.	Retorts at close of 1918.
ARKANSAS.				
Arkansas Zinc & Smelting Corporation	Van Buren	....	3,200	3,200
Athletic Mining & Smelting Co.	Fort Smith	....	....	2,496
Fort Smith Spelter Co.	........do	....	2,560	2,560
		....	5,760	8,256
COLORADO.				
United States Zinc Co.	Pueblo	2,208	1,984	2,208
ILLINOIS.				
American Zinc Co. of Illinois (A)	Hillsboro	4,000	4,864	4,864
Collinsville Zinc Smelter	Collinsville	1,792	2,304	*Idle*
Granby Mining & Smelting Co. (A)	East St. Louis	3,220	4,820	5,600
Hegeler Zinc Co. (A)	Danville	3,600	5,400	5,400
Illinois Zinc Co. (A)	Peru	4,640	4,640	5,520
Matthiesson & Hegeler Zinc Co. (A)	La Salle	6,168	6,168	6,168
Missouri Zinc Co.	Beckemeyer	352	352	352
Mineral Point Zinc Co. (A)	Depue	9,068	9,068	9,068
National Zinc Co. (A)	Springfield	3,200	4,480	4,480
Robert Lanyon Zinc & Acid Co. (A)	Hillsboro	1,840	3,200	3,200
Sandoval Zinc Co.	Sandoval	672	672	*Idle*
		38,552	45,968	44,652
INDIANA.				
Grasselli Chemical Co.	Terre Haute	....	....	4,200
KANSAS.				
American Spelter Co.	Pittsburg	896	992	*Dismantled*
American Zinc, Lead & Smelting Co.	Caney	6,080	6,080	*leased*
Do	Dearing	4,480	4,480	*Dismantled*

Chanute Spelter Co.	Chanute	1,280	1,280	"
Cherokee Smelting Co.	Bruce	896	896	*Idle*
Edgar Zinc Co.	Cherryvale	4,800	4,800	4,984
Granby Mining & Smelting Co.	Neodesha	3,760	3,760	*Dismantled*
Iola Zinc Co.	Concreto	660	1,320	"
Joplin Ore & Spelter Corporation	Pittsburg	1,444	1,792	"
Lanyon Smelting Co.	do	448	448	*Idle*
Owen Zinc Co.	Caney	1,280	1,920	"
Pittsburg Zinc Co.	Pittsburg	910	910	"
Prime Western Spelter Co. (A)	Gas	4,868	4,868	2,320
United States Smelting Co.	Altoona	3,960	4,600	*Dismantled*
Do	Iola	3,440	3,440	*Idle*
Do	La Harpe	1,924	1,926	*Dismantled*
Weir Smelting Co.	Weir		288	*Idle*
Do	Caney			4,352
MISSOURI.		41,126	43,800	11,656
Edgar Zinc Co.	St. Louis	2,000	2,000	*Dismantled*
Missouri Zinc Smelting Co.	Rich Hill		448	*Idle*
Nevada Smelting Co.	Nevada	672	672	"
OKLAHOMA.		2,672	3,120	
Bartlesville Zinc Co.	Bartlesville	5,184	6,336	6,336
Do	Blackwell		9,600	9,600
Do	Collinsville	10,752	13,440	*Dismantled*
Bartlesville Zinc Co. (Lanyon-Starr plant)	Bartlesville	3,456	3,456	3,456
Eagle-Picher Lead Co.	Henryetta		4,000	4,000
Henryetta Spelter Co.	do		3,000	3,000
Kusa Spelter Co.	Kusa	3,720	7,720	5,630
National Zinc Co.	Bartlesville	4,970	4,970	4,970
Oklahoma Spelter Co.	Kusa		1,600	*Idle*
Quinton Spelter Co.	Quinton		1,344	2,016

ACTIVE ZINC SMELTERS—Continued

Tulsa Fuel & Manufacturing Co.	Collinsville	6,232	6,232	6,232
United States Smelting Co.	Checotah		5,120	*Idle*
United States Zinc Co.	Sand Springs	5,680	8,000	8,000
Western Spelter Co.	Henryetta		2,400	3,200
		39,994	77,218	56,440
PENNSYLVANIA.				
American Steel & Wire Co. (A)	Donora	3,648	9,120	9,120
American Zinc & Chemical Co. (A)	Langeloth	3,648	7,296	7,296
New Jersey Zinc Co. (of Pennsylvania)	Palmerton	6,720	7,200	7,192
		14,016	23,616	23,608
WEST VIRGINIA.				
Clarksburg Zinc Co.	Clarksburg	3,648	3,648	*Idle*
Grasselli Chemical Co. (A)	do	5,760	5,760	5,760
Do	Meadowbrook	8,592	8,544	8,520
United Zinc Smelting Corporation (A)	Moundsville			1,728
		18,000	17,952	16,008
		156,568	219,418	167,028
PLANTS WITH SPECIAL RETORTS.*				
Eastern Zinc Refining Co.	Brooklyn, N. Y.		8	16
John Finn Metal Works	San Francisco, Cal.		2	12
Michael Hayman & Co.	Buffalo, N. Y.	12	12	12
M. M. S. Metal Co.	Trenton, N. J.		21	*Dismantled*
Trenton Smelting & Refining Co.	do	96	96	80
William Cramp & Sons Ship & Engine Building Co.	Philadelphia, Pa.	32	32	*Dismantled*
Total large retorts		140	171	120

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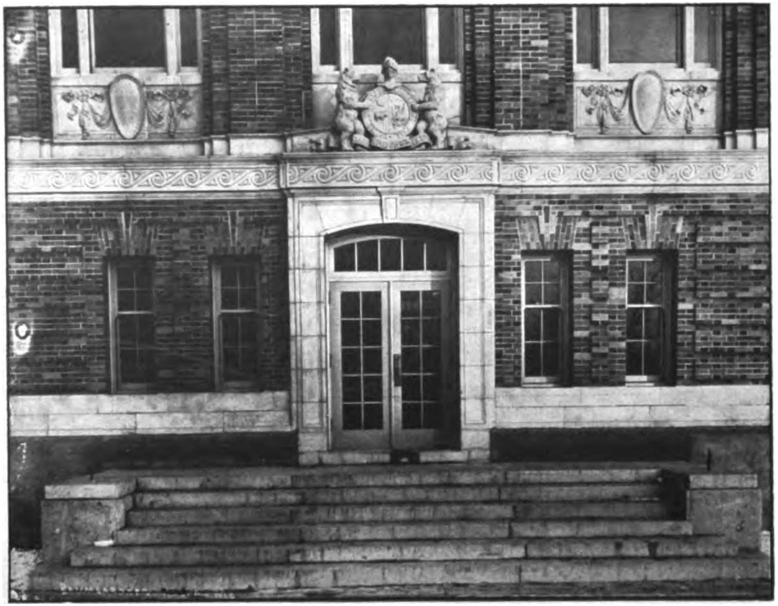
*Large graphite retorts yielding 600-800 pounds of spelter per charge.

ELECTROLYTIC ZINC PLANTS IN THE UNITED STATES, DECEMBER 31, 1918.

Company	Location of plant	Rated daily capacity	Remarks
American Smelting & Refining Co.	Murray, Utah	Experimental	Operated in 1916; idle in 1917-18
Anaconda Copper Mining Co.	Great Falls, Mont.	200 tons	Operated in 1917-18
Basin Salvage Co.,	Basin, Mont.	Experimental	Operated in 1917
Butters Electrolytic Zinc Syndicate	Martinez, Cal.	6 tons	Operated in 1918
Ducktown Sulphur, Copper & Iron Co.	Isabella, Tenn.	1 ton	Under construction
Electrolytic Zinc Co.	Baltimore, Md.	10 tons	Operated in 1917-18
Judge Mining & Smelting Co.	Park City, Utah	15 tons	Operated in 1918
River Smelting & Refining Co.	Keokuk, Iowa	20 tons	Operated in 1917-18
U. S. Smelting, Refining & Mining Co. (Mammoth)	Kennett, Cal.	25 tons	Operated in 1917-18
Western Chemical Co.	Denver, Colo.	10 tons	Under construction



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INDEX

of

Authors, Patentees and Subjects.

Numbers refer to items in the bibliography, not to pages. P before a number indicates that it refers to a patent or to an article about a patent.

The following abbreviations have been used: agt, agent; B.F., blast-furnace; chem., chemical; ppn, precipitation; ppt, precipitate; pptant, precipitant; smtg, smelting; zn, zinc.

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TECHNICAL SERIES

AN INVESTIGATION OF BLENDED PORTLAND CEMENT

ROLLA, MISSOURI
1918

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SCHOOL OF MINES AND METALLURGY

UNIVERSITY OF MISSOURI

AN INVESTIGATION OF BLENDED PORTLAND CEMENT

By

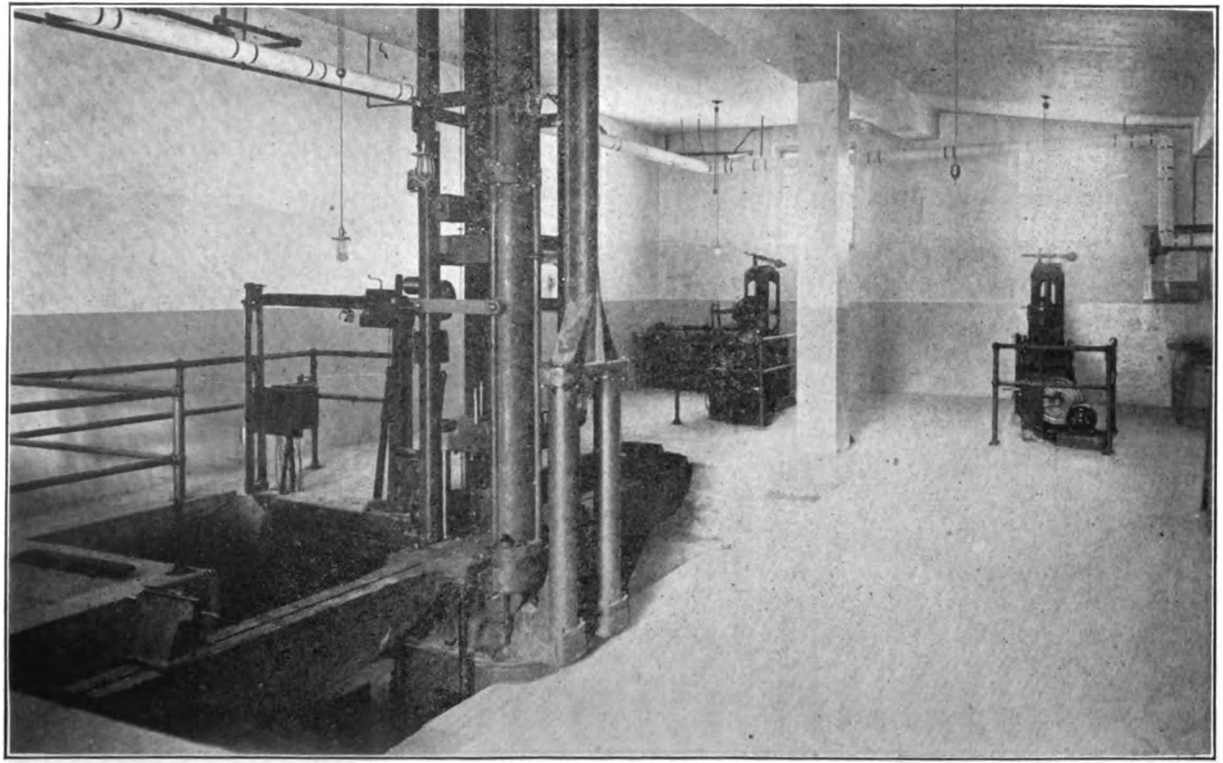
EDGAR S. McCANDLISS, C. E.,*
Assistant Professor of Civil Engineering

And

HENRY H. ARMSBY, C. E.,
Assistant Professor of Civil Engineering

*On leave, Captain 314 Engineers, A. E. F.

ROLLA, MISSOURI
1918



VIEW IN MATERIALS TESTING LABORATORY

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John Russell Stubbins[7]	*Student Assistant*
John Munson Morris[8]	*Student Assistant*

[1] On leave—Captain, 314 Engineers, A. E. F.

[2] On leave—1st Lieut. U. S. Engineers, A. E. F.

[3] Student Assistant 1915-16 and 1917-18.

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[5] 1916-17.

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BULLETIN
OF THE
School of Mines and Metallurgy
UNIVERSITY OF MISSOURI
TECHNICAL SERIES

VOL. IV MAY, 1918 No. 4

INTRODUCTION

In the fall of 1913 in conjunction with the regular classwork in the cement testing laboratory of the Missouri School of Mines Prof. McCandliss undertook the study of the behavior of sand-blended cements. The results obtained were somewhat surprising, but owing to the limited facilities for carrying on the work, extended investigations were not made at that time. But in 1915 with the installation of the present well equipped laboratory for the testing of materials, it became feasible to carry out experimentation along more extensive lines. One of the problems to receive attention was the continued study of sand-blended cements.

The questions taken up were:

1. Can Portland Cement be blended with sand to produce a sand-blended cement having the same general physical properties as Portland Cement?
2. What amount of sand can be blended with Portland Cement without materially impairing the strength of the blended mixture?
3. In grinding cement clinker, does introducing sand with the clinker in a tube or ball mill facilitate fine grinding?

About three thousand test specimens for tension and compression have been prepared. In order that differences due to personal equation might not effect the results all of these specimens were prepared by Prof. McCandliss. It was planned to have the tests extend over a period of two years. The work was started in the fall of 1915 and carried on under the direction of Prof. McCandliss until he entered the military service in the spring of 1917. In the fall of 1917 the work was turned over to Prof. Armsby, who completed the tests in 1918.

A previous bulletin of this series (Vol. III, No. 3) gave the results obtained under question 1 for one year. This bulletin includes the matter therein presented, with the addition of the remaining tests for the complete series for two years.

The authors take pleasure in thanking the various cement companies for their co-operation in supplying the cement for these investigations. They are indebted to Mr.

H. A. Buehler, Director of the Missouri Bureau of Mines and Geology, for his assistance and advice, and to Messrs. B. L. Ashdown, E. C. Burkhart, C. E. Bardsley, T. C. Gerber, J. M. Morris, W. H. Reber, and J. R. Stubbins, students in the Missouri School of Mines and Metallurgy, for their cheerful assistance.

CALCAREOUS CEMENTS

The term cement has been applied: To any substance or composition which at one temperature or one degree of moisture is plastic and at another is tenacious; to adhesive mixtures employed to unite objects or parts of objects; to any material, capable of adhering to and uniting into a coherent mass, fragments of a substance not in itself adhesive; to any substance which by hardening causes objects between which it is applied to adhere firmly; to a tenacious infusible substance; to an adhesive or viscous substance; in general to any substance capable of uniting or tending to unite particles of matter into a compact whole. Lutes, glues, solders, gums, putty, mucilage, plasters, limes, hydraulic cements, and similar substances are all comprehended in this definition. Such a definition embraces a large variety of substances which differ one from another in composition, behavior, and importance, and have but few charactistics in common. Because of this, the term cement has become more or less generally restricted to the designation of that group or adhesives which is employed in the construction of engineering works. Cements of this kind bear a chemical relationship to each other, consisting as they do of mixtures which contain compounds of lime as their principal ingredient, in consequence whereof they are termed calcareous cements. Of these the most important by far is Portland Cement.

Portland Cement is a composition, the principal constituents of which are compounds of lime and clay. The abundance of these substances in nature, and the usefulness and cheapness of the cement combine to make it a universal material of construction.

The manufacture of Portland Cement is a highly specialized art, but in general it may be briefly outlined as follows: The clay and the lime are artificially mixed in predetermined proportions depending upon the purity of the materials. This mixture is reduced by grinding to a fine powder and the product roasted at a high temperature. This roasting causes the powder to undergo chemical and physical changes and the result is a semi-vitrified clinker. This clinker is commonly adjudged to be inert, or devoid of the properties of cements, but when reduced to an extremely fine powder the finest particles possess the property of cements. Hence, in general, Portland Cement may be defined as the material obtained by finely pulverizing the clinker produced by calcining to incipient vitrification an intimate artificial admixture of properly proportioned argillaceous and calcareous substances.

BLENDED CEMENTS

Why it is that the particles of the cement clinker are inert when of appreciable size and that those of inappreciable size are active, has never been conclusively determined. Nor has the exact size or upper limits in size of the active particles been ascertained. It has, however, been conclusively demonstrated that any particle which will not pass through a standard No. 200 screen has no cementing properties and also that such particles as do pass through this screen are not necessarily active, but that a considerable percentage of them are practically inert. The present standard specifications for fineness of Portland Cement permit of 22% by weight to be retained on a standard No. 200 sieve. Hence it follows that commercial Portland Cement is a material composed of both active and inert particles, the latter being inactive on account of their physical coarseness and their amount being a large percentage of the cement. The desirability of continuing the grinding to reduce this percentage of inactive clinker has been a much discussed problem. But since the apparent increase in strength in the cement is not in proportion to the increased cost of manufacture, and also since the physical behavior of the cement so changes with continued grinding that it sets more rapidly, it appears that the economic limit of grinding cement clinker has been reached. On the other hand, the very fact that these inert particles are present in the cement in large amounts and that they are in reality dormant cement, needing only the energy to break them down to bring out their latent cementing qualities, suggests the presence of a considerable economic waste. If it is necessary to maintain the present graduation in the size of the particles in order to control the behavior of the cement, it is quite possible that some other substance less expensive than cement clinker can be used for the large size particles. In other words, if it is necessary to have these inert particles present in the cement, there are other inert substances in nature, which might be used as a substitute for the inert clinker particles in case the substitution could be made, thus permitting the further reduction of the clinker into active cement. It is assumed that such a substitution can be accomplished and it is here proposed to study the effect of such procedure.

The product obtained by mixing Portland Cement with some other finely pulverized substance in a dry condition before being used in mortar or concrete, is commonly termed "blended cement." The substance which is mixed with the Portland Cement is designated the "blending material, or the blend." This latter may be either entirely inactive as a cement or may possess cementing qualities.

The blending of Portland Cement is no innovation as the practice probably made its first appearance in the early nineties. But, owing to the rapid development of the Portland Cement industry with the accompanying reduction in the cost of the product, the practice has been largely discontinued. These cements were manufactured in general by merely mixing the ingredients, Portland Cement and the blend, in a ball or tube mill, no especial effort being made to continue the grinding of the cement. This product was marketed under various trade names such as "silica cement," "sand cement," "tufa cement," etc., the name depending largely upon the nature of the blending material used. While these cements have no importance in present construction as a general proposition, still the economic advantages derived from such methods have not passed into absolute obscurity. Several noteworthy instances might be cited where large constructions have been carried on in which blended cement has been used with satisfaction, whereby considerable economies have been effected. Among the more recent and important of these are the works of the U. S. Reclamation Service and the Los Angeles Aqueduct Commission. In these undertakings the justification for using blended cements has been based largely upon the excessive transporation charges due to the remoteness of the projects from industrial centers. While this condition existed, it is unfortunate that thereby the inference has been given that otherwise blended cements would not have been used, for it is quite possible that in creating this impression an injustice has been done to a worthy practice. The theory has also been advanced that only materials containing active or colloidal silica are suitable for blending Portland Cement. This, of course, excludes quartz sand, and here again it is possible that an erroneous notion is conveyed, for, although it is not proposed to discuss the relative merits of quartz sand as a blend, yet an endeavor will be made to show that it can be used satisfactorily for this purpose.

MATERIALS

In selecting the cements for use in this investigation, an effort was made to choose such brands of Portland Cement as would give some range in the character of the component raw ingredients. Three commercial Portland Cements were used, viz: Atlas, Lehigh, and Red Ring. The composition of the Atlas Portland Cement is Mississippian Limestone and Pennsylvanian shale; that of the Lehigh Portland Cement is hard Mitchell (Mississippian) limestone and shale; and that of the Red Ring Portland Cement, Mississippian limestone, Pennsylvanian shale, together with Loess clay. There is no special difference in the methods used in manufacturing these three cements.

The blending material used was a natural quartz sand from Ottawa, Illinois. It was supplied by the Ottawa Silica Company and is marketed under the trade name of "Banding Sand." This sand is quite fine but well graded and with but slight sifting was found to conform closely in gradation to the coarser particles in the Portland Cement, and was therefore a suitable substitute for them in making the blended cements.

For mortar specimens, standard Ottawa sand was used.

Each of these materials was received at the laboratory in good condition and stored in suitable containers. The Portland Cements were each passed through a No. 20 sieve before storing, to insure uniformity throughout the samples and to remove large lumps.

SCOPE OF TESTS

Two separate series of tests are included in this report, which are called, for convenience, Series I and Series II. These two series will be taken up separately.

SERIES ONE

DESCRIPTION

Series I comprises the tests originally outlined for the investigation, and comprises three Divisons, called A, B, and C. These three Divisions are made up in exactly the same manner, but using different brands of cement; Division A using Atlas Portland Cement, Division B using Lehigh Portland Cement, and Division C using Red Ring Portland Cement. A Division consists of the cement itself and four blended cements. These blended cements were composed of (1) such part of the Portland Cement as easily passed a No. 200 sieve, and (2) quartz sand, all of which passed a No. 65 seive, and about seventeen per cent of which passed a standard No. 200 seive. These blended cements, for convenience of identification, are designated A_{10}, A_{20}, A_{30}, and A_{40}, the numerals indicating the percentage by weight of sand present in the blended cement.

PURPOSE

The purpose in view in making up this series was to study the behavior of blended cements made up in such a way as to approach as closely as possible to the same range in gradation in size of particles as occurs in the original Portland Cement. In other words, it was proposed to remove from the Portland Cement the large, inert particles and to substitute for them other inert particles of about the same size. No accurate means were devised for determining the precise amount of the particles removed from the Portland Cement, and therefore several combinations were used which it was thought would give sufficient range to obtain a satisfactory comparison. The end desired was to ascertain whether it is essential in Portland Cement, in order to maintain its present physical characteristics, to have unpulverized clinker for the coarser particles or whether a fine sand would serve the purpose equally well, sand being used because of its having no cementing tendencies, and because of its abundance in nature.

PROCEDURE

Coarse particles were removed from the Portland Cements by screening through a standard No. 200 sieve and those of the banding sand by screening through a No. 65 sieve. Enough of each of these materials was then weighed out to produce 500 or 1,000 grams of blended cement in the proportion desired, 500 grams being used in making the test specimens for tension and 1,000 grams the specimens for compression. The sand and cement were then mixed by pasing the mixture through a No. 35 screen six times. The resulting blended cement was uniform in color and had every indication of being well combined. It was noted, however, that the materials separated slightly if the containers were dropped lightly upon the table a few times, a fine rim of sand appearing about the base of the cone of the cement. Therefore extreme care was taken not to disturb the blended cements after they were made until they were formed into test specimens.

Chemical analyses were made of each of the materials. and on each cement of each Division the following physical tests were made: (a) Neat tension, (b) mortar tension (c) neat compression, (d) mortar compression, (e) normal consistency, (f) time of setting, (g) constancy of volume (normal and accelerated tests), (h) fineness and sieve analysis and (i) specific gravity. The methods for testing cement recommended by the American Society of Civil Engineers (See Transactions Vol. 75) were followed but with the following exceptions: A sieve analysis was made of each of the cements. The percentage of water used in making mortar specimens was increased one per cent above the recommended values. Sufficient specimens for neat and mortar tension and compression were made to permit of making tests at intervals up to and including two years, the average of three breaks constituting a test.

Compressive test specimens were cylinders two inches in diameter and two inches high. They were made in wooden moulds which had been especially prepared for the purpose. These moulds were twelve inches long, four inches wide, and two inches high, and were made in two sections. The sections were held together with dowels and bolts and were provided with three two-inch holes symmetrically placed on the axis of the block. Poplar wood was used, and the moulds were finished and painted and, as an added precaution against absorption of the water from the specimens, the moulds were greased with hard engine oil each time before being used. The moulds were satisfactory, and good specimens were obtained. No tamping device was used, all moulds being filled by hand.

Compression tests were made with two-screw testing machine of the Riehle type, having a capacity of 50,000 pounds. Each specimen upon being removed from the storage tank was calibrated and weighed to ascertain the relative density. The specimens were at once mounted in the machine on a hemispherical bearing plate and imbedded in plaster of Paris. After centering the specimen in the machine, a light initial load was applied. After the plaster had hardened, continuous load was applied, the moving head of the testing machine travelling at a rate of about .06 inch per minute until failure. The load when first crack appeared in the specimen, as well as the ultimate load, was recorded. These loads were reduced to unit stresses for comparison.

Each of the blended cements was put through the same tests as the Portland Cements except that the chemical analysis and specific gravities were computed and not determined experimentally and no determinations for fineness or sieve analysis were made. In preparing the blended cements each test was prepared separately, only enough of the materials being laid out at a time to make three test specimens.

RESULTS OF TESTS

The complete detailed results of all tests made in this investigation are tabulated and appended to this report in Appendix B. For ease and convenience in reading the results, Appendix A has been prepared, giving only the final average results as they appear in the tables of Appendix B. The tables of Appendix A were used in plotting the curve sheets which follow in the discussion. These curve sheets were prepared to facilitate the interpretation of the tabulated results. Tables of comparative strengths have also been prepared, and these are also included with the discussion which follows.

(A) Neat Cement in Tension.

On curve sheet No. 1 are plotted the results obtained from tension tests of Atlas Portland Cement "A" and the blended cements made from the same. (See Table A, Appendix A). It will be noted from the curves here shown that each of these cements meets the requirements for neat cement in tension of the standard specifications of the American Society for Testing Materials (1916), which are 175; 500 and 600 pounds at twenty-four hours, seven days, and twenty-eight days respectively. In each case the maximum strength is attained within the first twelve weeks. Cement A, the Portland Cement, attains the greatest maximum strength. For comparison of relative strengths, Table I has been compiled. It is intended to show in this table the relative strengths of the five cements at the various ages of testing, the values one to five being assigned to the various relative strengths in their order of importance, 1 indicating the cement developing maximum strength and 5 indicating the one developing the minimum strength at the same period.

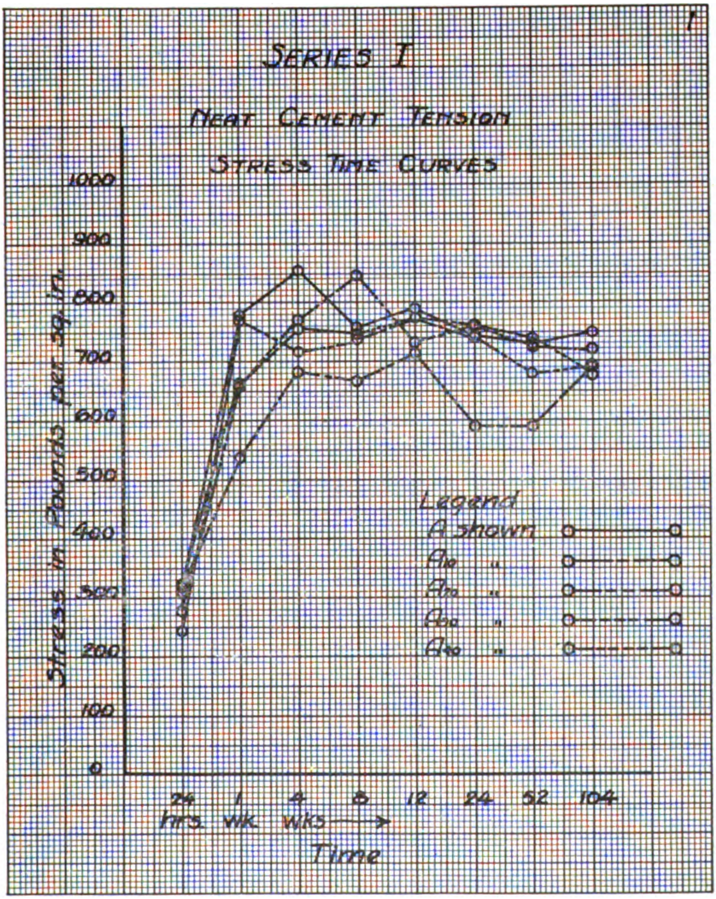
TABLE I

Series I

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52	104
A	1	1	1	2	1	3	3	1
A_{10}	2	5	5	5	5	5	5	4
A_{20}	5	2	4	4	3	4	4	3
A_{30}	4	3	2	1	4	2	1	5
A_{40}	3	4	3	3	2	1	2	2

From Table I it is seen that cement A ranges first in point of strength except for the 24- and 52-week tests, in which it is outranked by cements A_{30} and A_{40}. A_{10} appears to be the weakest throughout the run of the tests, A_{20} next with A_{30} and A_{40} only slightly inferior to A after 12 weeks. From Curve Sheet 1 it appears that A_{30} and A_{40} attain their strength somewhat more slowly than A, but are nearly as strong after 12 weeks.


I
SERIES I
NEAT CEMENT TENSION
STRESS TIME CURVES
Stress in Pounds per sq. in.
1000
900
800
700
600
500
400
300
200
100
0
24 hrs.
1 wk
4 wks
8
12
24
52
104
Time
Legend
A shown
A10 "
A20 "
A30 "
A40 "

On Curve Sheet 2 are plotted the results obtained from tests of Lehigh Portland Cement, "B", and the blended cements from the same. (See Table A, Appendix A). Each of these cements meets the requirements of the standard specifications of the American Society for Testing Materials (1916). It is to be noted also that in each case the maximum strength is attained within the first twelve weeks. Cement "B" attaining the greatest maximum strength. Table II is similar to Table I.

TABLE II

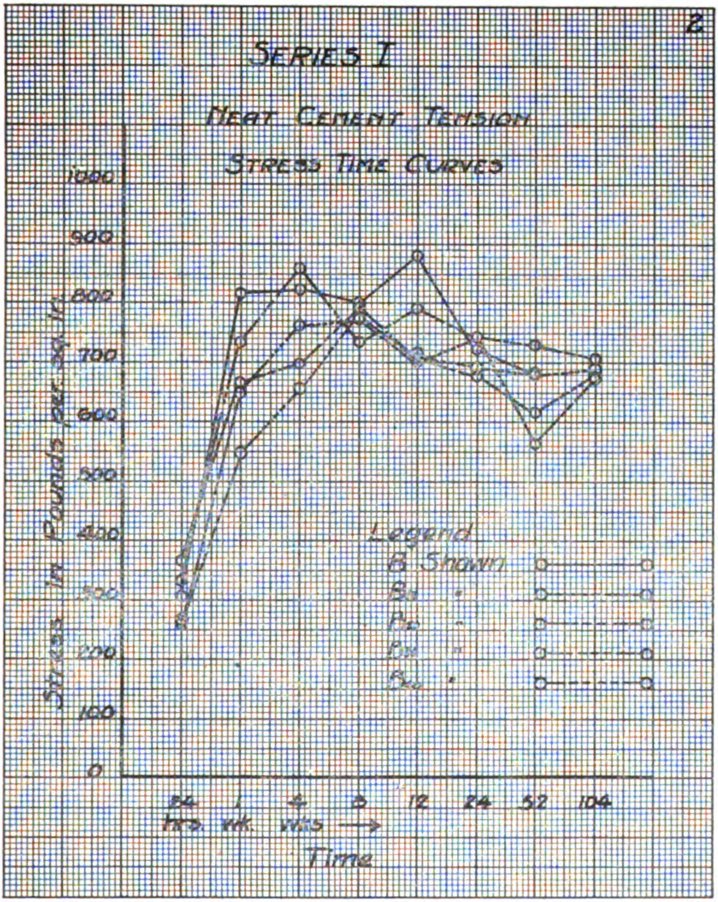
Series I

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52
B	3	1	2	1	1	3	3
B_{10}	1	3	4	2	4	5	4
B_{20}	2	2	1	5	2	1	5
[illegible]	5	4	3	3	3	2	1
B_{40}	4	5	5	4	5	4	2

From Table II Cement B seems to rank first in relative strength up to and including twelve weeks. Over this period of time B_{20} ranks second, B_{10} third; B_{30}, fourth; and B_{40}, fifth. This relationship is not pronounced, however, there being several conflicts. It is quite apparent, however, that after twelve weeks B_{30} and B_{40} increase in relative importance and are equal or superior to B, while B_{10} and B_{20} make a relative less favorable showing. From Curve Sheet 2 it is seen that B_{30} develops the most uniform strength throughout the entire period of testing.

Unfortunately the specimens for the 104-week tests were lost, so no results can be given for this age.


2
SERIES I
NEAT CEMENT TENSION
STRESS TIME CURVES
Stress in Pounds per sq. in.
1000
900
800
700
600
500
400
300
200
100
0
24
1
4
8
12
24
52
104
hrs. wk. wks →
Time
Legend
B Shawn

On Curve Sheet 3 are plotted the results obtained from testing Red Ring Portland Cement "C" and blended cements made from the same, in tension. (See Table A, Appendix A). Each of these cements meets the requirements of the standard specifications of the American Society for Testing Materials (1916) In each case the maximum strength was attained in twelve weeks. Cement "C" attains the greatest maximum strength. Table III is similar to Table I.

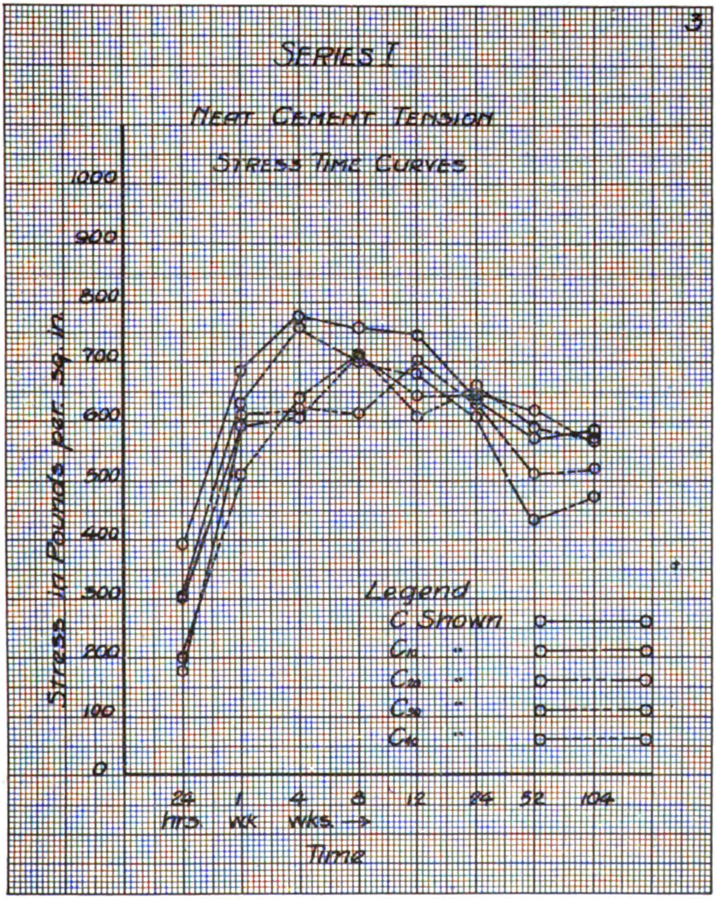
TABLE III

Series I

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52	104
C	1	1	1	1	1	3	3	1
C_{10}	3	2	2	2	3	5	5	5
C_{20}	2	3	4	5	2	4	4	4
C_{30}	5	4	5	4	5	1	2	2
C_{40}	4	5	3	3	4	2	1	3

From Table III it is seen that the cements in this Division follow practically the same variations in relative strength as those in the "A" Division, with C ranking first. C_{30} and C_{40} only slightly inferior, C_{20} ranking fourth and C_{10} last.


3
SERIES I
NEAT CEMENT TENSION
STRESS TIME CURVES
Stress in Pounds per. Sq. in.
1000
900
800
700
600
500
400
300
200
100
0
24 hrs.
1 wk
4 wks. →
8
12
24
52
104
Time
Legend
C Shown
C_{10} "
C_{20} "
C_{30} "
C_{40} "

On Curve Sheet 4 are plotted the results obtained by averaging the corresponding tests plotted on Curve Sheets I, II, and III. (See Table A "Average of averages," Appendix A). From this Curve Sheet it is seen that in each case the requirements of the standard specifications of the American Society for Testing Materials (1916) are satisfied. The maximum tensile strength is attained in each case in the first twelve weeks. The average of the commercial Portland Cements attains the greatest maximum strength. Table IV is similar to Table I.

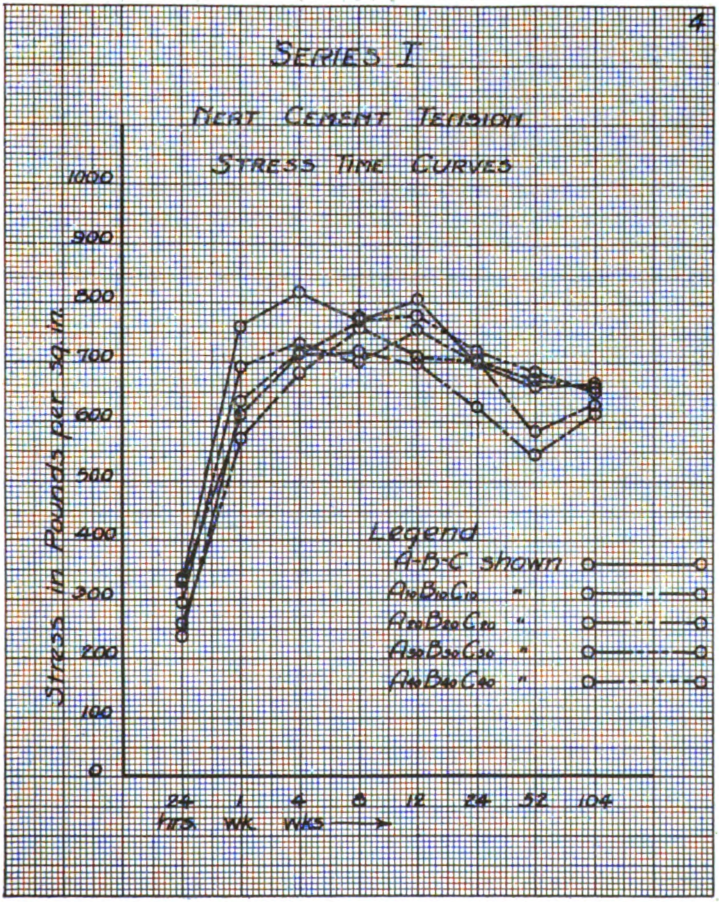
TABLE IV

Series I

RELATIVE STRENGTHS

Age of test in weeks	(24 hr.)	1	4	8	12	24	52	104
A-B-C	1	1	1	1	1	3	3	1
A[illegible] B[illegible] C[illegible]	2	4	3	4	5	5	5	5
A_{20} B_{20} C_{20}	3	2	2	5	3	4	4	4
A_{30} B_{30} C_{30}	5	3	3	2	2	1	1	3
A_{40} B_{40} C_{40}	4	5	5	3	4	2	2	2

From Table IV it is seen that the "Average of averages" curves conform to the same variations as the single curves do, with the same relative ranks for the different blends. It is to be noted in all these curves that the changes in relative rank in the 24- and 52-week tests are not due to increased strengths in the cements containing 30 and 40 per cent blend, but rather to decreasing strengths in the others. The average of the cements with a blend of 45 per cent develops a strength at the age of about four weeks. This strength it retains quite consistently as the age increases during the fifty-two weeks of test. The maximum range in variation during this period is about 70 pounds or about ten per cent of the average strength developed. It is interesting to note that the average variation or range in the strengths at the successive periods of testing is about 120 pounds. From a comparison of Curves A, B, and C from Curve Sheets 1, 2, 3, it is seen that the average variation in strength of these commercial cements is about 108 pounds. From this observation, it would seem that had commercial Portland Cements been tested instead of the blended cements and in all other respects had the results been averaged as


4
SERIES I
NEAT CEMENT TENSION
STRESS TIME CURVES
Stress in Pounds per sq. in.
1000
900
800
700
600
500
400
300
200
100
0
24 hrs.
1 wk.
4 wks
8
12
24
52
104
Legend
A-B-C shown
A10B10C10 "
A20B20C20 "
A30B30C30 "
A40B40C40 "

has been done on Curve Sheet 4, there would have been developed a variation in the strengths practically as great as shown here. In other words there seems to be but little more variation in the strength shown on curve sheet 4 than might reasonably be expected from that number of commercial Portland Cements, and that in the matter of neat cement in tension within the scope of this investigation the blended cements compare favorably with commercial Portland Cements.

(B) Cement Mortar in Tension.

On Curve Sheet 5 are plotted the results of tests for tension of 1 to 3 mortar specimens of Atlas Portland Cement A and blended cements of the same. (See Table B, Appendix A). It will be noted that with the exception of Cement A each of the cements satisfied the requirements of the standard specifications of the American Society for Testing Materials for mortar briquettes in tension, which for 1916 are 200 and 275 pounds per square inch at the ages of seven and twenty-eight days respectively. The specifications for 1917 require 300 pounds per square inch to be developed at the age of twenty-eight days. In each case the maximum strength is attained in the first twelve weeks. Cement A attains the least maximum strength. Cement A_{40} attained a strength of about 350 pounds at four weeks and main tained this strength throughout the remainder of the period. The maximum variation after the first four weeks was about 300 pounds. For the comparison of relative strengths Table V has been prepared. It is similar to Table I.

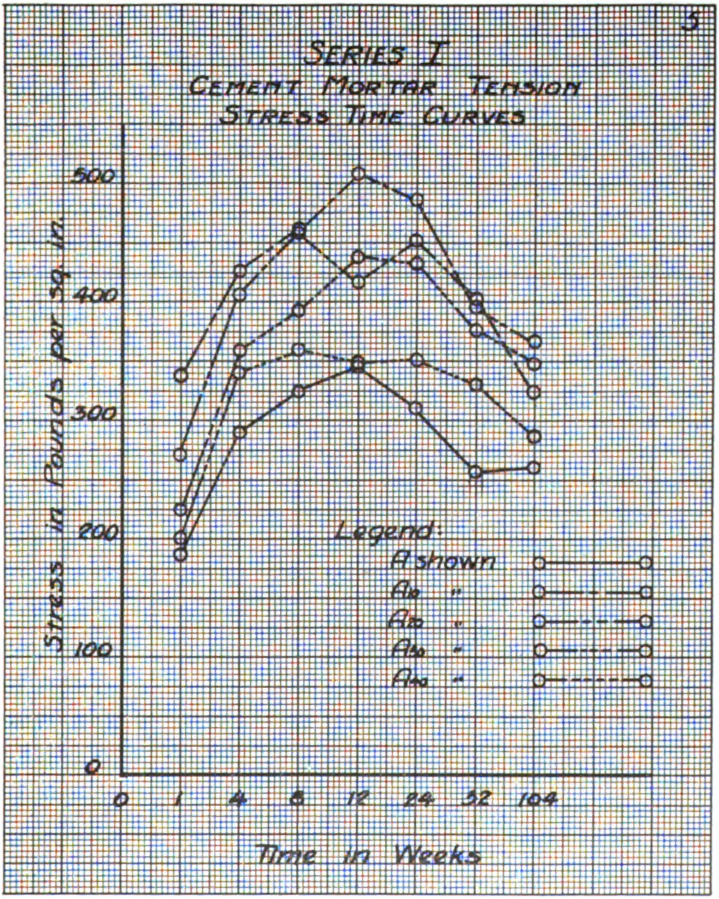
TABLE V

Series I

RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52	104
A	5	5	5	5	5	5	5
A_{10}	1	1	1	1	1	2	1
A_{20}	2	2	2	3	2	1	3
A_{30}	3	3	3	2	3	3	2
A_{40}	4	4	4	4	4	4	4

From Table V it is seen that in relative strength A_{10} ranks first; A_{20}, second; A_{30}, third; A_{40}, fourth, while the commercial Portland Cement "A" ranks last throughout the entire period of testing.


5
SERIES I
CEMENT MORTAR TENSION
STRESS TIME CURVES
Stress in Pounds per sq. in.
500
400
300
200
100
0
0
1
4
8
12
24
52
104
Time in Weeks
Legend:
A shown
A10 "
A20 "
A30 "
A40 "

On Curve Sheet 6 are plotted the results of tests for tension of 1 to 3 mortar specimens of Lehigh Portland Cement "B", and blended cements of the same. (See Table B, Appendix A). It will be noted that each of these cements meets the requirements of the standard specifications of the American Society for Testing Materials (1916 or 1917), for mortar briquettes in tension. Cements B and B_{40} are considered as conforming with the 1917 specifications at an age of one week, with strengths of 197 and 194 pounds per square inch, respectively, in view of their showing at the age of four weeks. Maximum strengths are attained within the first twelve weeks except in the case of B_{10} which shows a maximum strength at fifty-two weeks. Table VI is similar to Table I.

TABLE VI

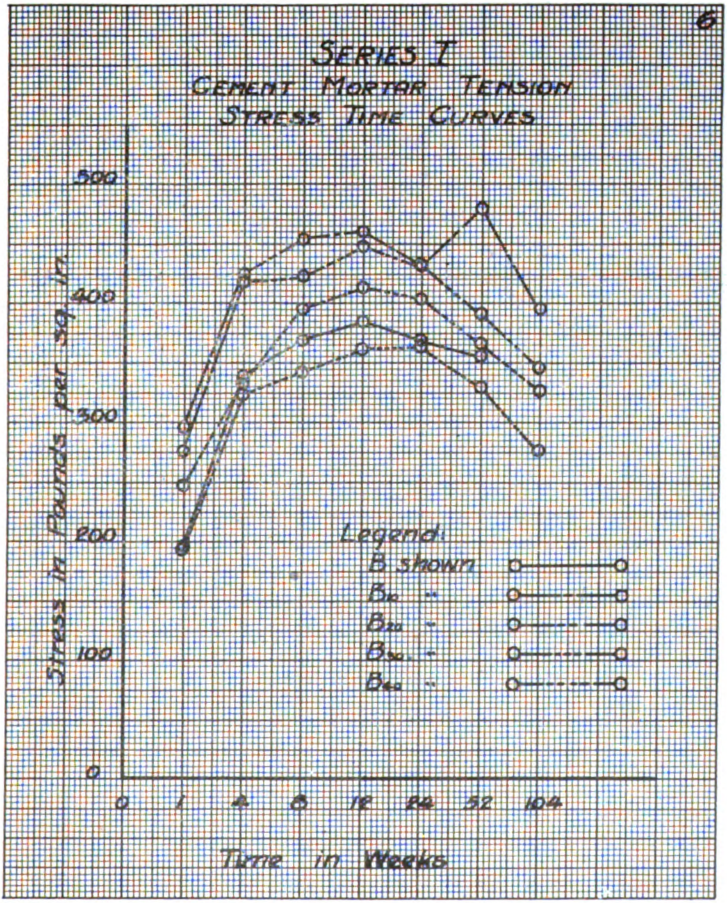
Series I

RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52
B	4	4	4	4	4	4
B_{10}	1	1	1	1	1	1
B_{20}	2	2	2	2	2	2
B_{30}	3	3	3	3	3	3
B_{40}	5	5	5	5	5	5

By reference to Table VI it is seen that B_{10} easily ranks first in relative strength throughout the entire period of tension; B_{20}, second; B_{30}, third; "B", fourth; and B_{40}, fifth.

Unfortunately the specimens for the 104-week tests were lost, so no results can be given for this age.


6
SERIES I
CEMENT MORTAR TENSION
STRESS TIME CURVES
Stress in Pounds per sq. in.
500
400
300
200
100
0
0
1
4
8
12
24
52
104
Time in Weeks
Legend:
B shown
B_{10} "
B_{20} "
B_{30} "
B_{40} "

On Curve Sheet 7 are plotted the results of the tests for tension of 1 to 3 mortar specimens of Red Ring Portland Cement "C" and blended cements of the same. (See Table B, Appendix A). These results seem to be less uniform than those shown on the two previous curve sheets. It will be noted, however, that each of these cements satisfactorily meets the requirements of the standard specifications of the American Society for Testing Materials of mortar briquettes in tension (1916). In each case the maximum strength is attained within the first twelve-week period. Table VII is similar to Table V.

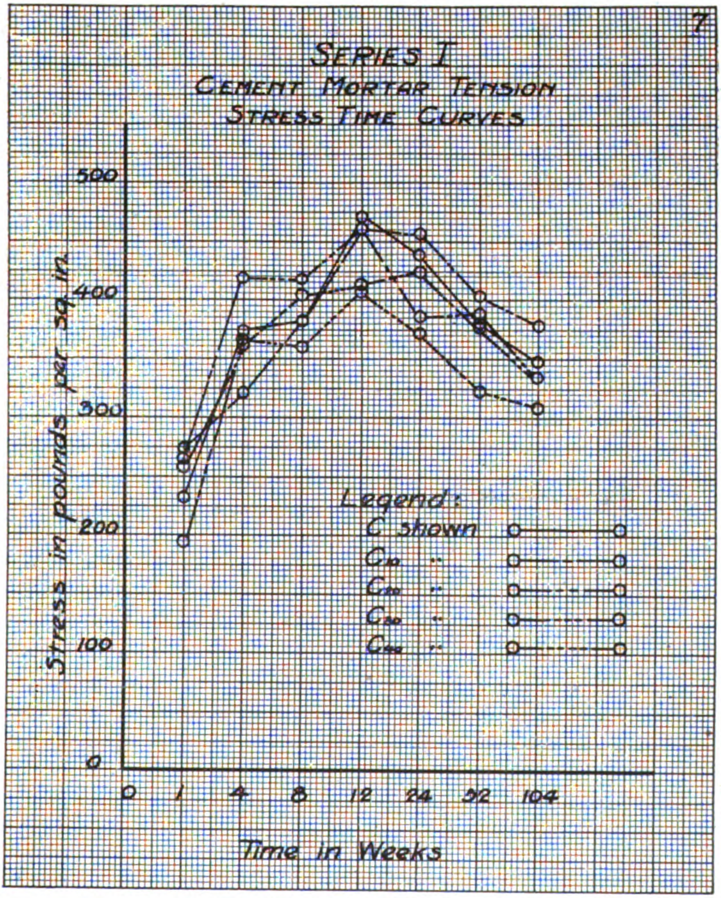
TABLE VII

Series I

RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52	104
C	4	2	3	1	2	3	2
C_{10}	1	4	3	1	1	1	1
C_{20}	2	1	1	3	4	2	3
C_{30}	3	5	2	4	3	4	3
C_{40}	5	3	5	5	5	5	-5

From Table VII, while it is more difficult to fix relative strength than in some of the previous cases, it is apparent that C_{40} should be classified last or fifth in strength; C_{30} should probably receive fourth place; of the remainder, the classification is more difficult and less well defined, but the classification suggested places C_{10} first, C_{20} second, and C third. It will be noted that this classification corresponds to the relative strengths developed at 1, 12, and 52 weeks, respectively.


7
SERIES I
CEMENT MORTAR TENSION
STRESS TIME CURVES
Stress in pounds per sq. in.
500
400
300
200
100
0
0
1
4
8
12
24
52
104
Time in Weeks
Legend:
C shown
C_{10} ..
C_{20} ..
C_{30} ..
C_{40} ..

The values plotted on Curve Sheet 8 represent the results obtained by averaging corresponding values from those plotted on Curve Sheets 5, 6, and 7. (See Table B, "Average of averages," Appendix A). The results obtained from averaging A, B, and C, the three specimens of commercial cement mortar in tension, should represent approximately the behavior of an average commercial Portland Cement. This curve sheet corresponds with Curve Sheet 4 except that the latter is for neat cement in tension. It will be noted here that each of these cements satisfies the requirements of the standard specifications of the American Society for Testing Materials (1916) for cement mortar in tension. Each of the cements attain maximum strength during the first twelve weeks. The differences in strength at any age is not radical, 100 pounds being an approximate average range in strength. For ascertaining relative strengths Table VIII is shown which is similar to Table I.

TABLE VIII

Series I

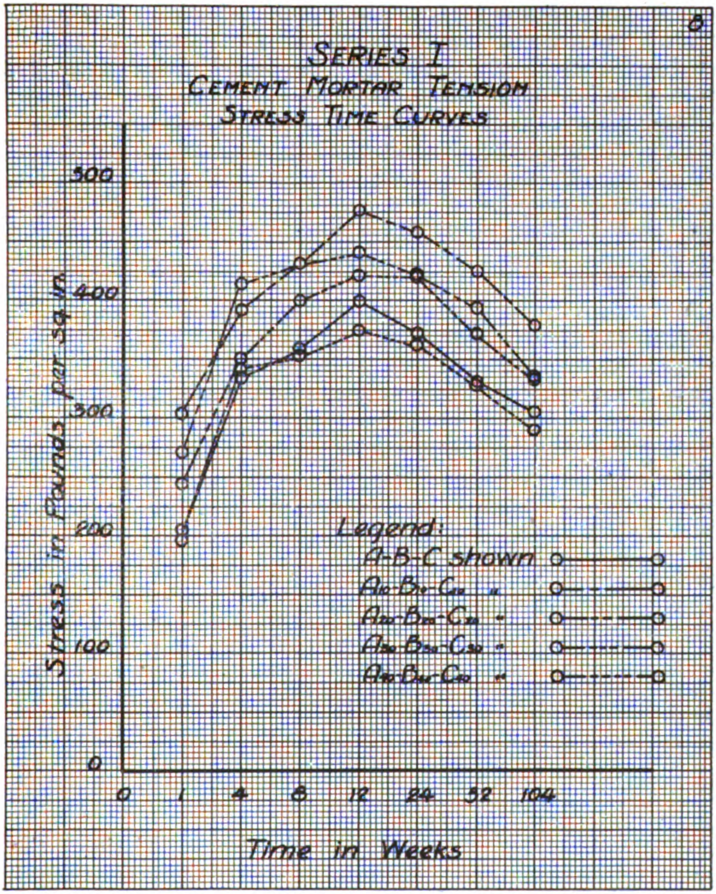
RELATIVE STRENGTHS

Age of test in weeks	1	4	8	12	24	52	104
A B C	4	5	4	4	4	4	4
A_{10}, B_{10}, C_{10}	1	2	1	1	1	1	1
A_{20}, B_{20}, C_{20}	2	1	1	2	2	2	3
A_{30}, B_{30}, C_{30}	3	3	3	3	3	3	2
A_{40}, B_{40}, C_{40}	5	4	5	5	5	5	5

Table VIII gives the following classifications: A_{10}, B_{10}, C_{10}, first; A_{20}, B_{20}, C_{20} second; A_{30}, B_{30}, C_{30} third; A, B, C fourth; and A_{40}, B_{40}, C_{40}, fifth. By reference to Curve Sheet 8, it is seen that there is but little difference in strength in A, B, C and A_{40}, B_{40}, C_{40}. In the case of cement mortar in tension, the results of these investigations show that the blended cements are equal or superior to Portland Cement.

(C) Neat Cement In Compression.

The results obtained from each cement in compression cannot be considered satisfactory in all respects. They are apparently inconsistent and contradictory. Tests of a cement made at different time periods seem to follow no general law. In some cases, maximum strengths occur with the oldest tests; in others, at the early test periods. The


8
SERIES I
CEMENT MORTAR TENSION
STRESS TIME CURVES
Stress in Pounds per sq. in.
500
400
300
200
100
0
0
1
4
8
12
24
52
104
Time in Weeks
Legend:
A-B-C shown
A_{10}-B_{10}-C_{10} "
A_{20}-B_{20}-C_{20} "
A_{30}-B_{30}-C_{30} "
A_{40}-B_{40}-C_{40} "

cause of this eccentricity in results is not apparent. Extreme care was maintained throughout the entire period of experimentation in order to secure uniform conditions, and it is felt that all specimens were treated substantially alike. If it is characteristic of neat cement in compression to show no more uniformity in the results than those here obtained, there seem to be no data available to establish the fact. It is significant, however, that the results obtained from the Portland Cements are no more consistent than those gotten from the blended cements, and in no single instance do the results obtained show uniformity of behavior throughout. The like blended cements of the three commercial Portlands show but slight similarity and the commercial Portlands differ one from the other in behavior. The results obtained are submitted without further apology, but it is hoped that further experimentation will afford a basis for a satisfactory explanation of the behavior of these cements in compression. Attention is called to the fact that this is not a standard test, and in consequence there is no specification to be satisfied, but none of all of these tests, with but a single slight exception, falls below the limit of safety for most large buildings, that is 5000 pounds per square inch.

On Curve Sheet 9 are plotted the results obtained from testing Atlas Portland Cement "A" and blended cements of the same in compression (neat). (See Table C, Appendix A.) As has been noted, there seems to be no uniformity in the behavior of the various curves. Cement "A" shows a substantial increase in strength throughout the duration of the test, and it would appear that the maximum strength which this cement may attain has not been reached. Unfortunately the 104-week specimens were lost, so that it can not be stated as a fact, but it is probable that the strength developed at 52 weeks would not be greatly increased at later periods.

Cement A_{10} follows closely cement A within the first 24 weeks, there being but slight preference between them. The unusual drop experienced in the 52- and 104-week tests of A_{10} is one of the surprises encountered.

Cement A_{20} develops no unusual characteristics, the average result throughout the entire period being fairly consistent. The same may be observed of A_{30}. The most unusual development in the tests of A_{40} seems to be the relatively low strength at 52 weeks.

Table IX is similar to the previous tables, used in comparing relative strength at the various time-intervals, numerals 1 - 5 being assigned to the highest and lowest strengths.

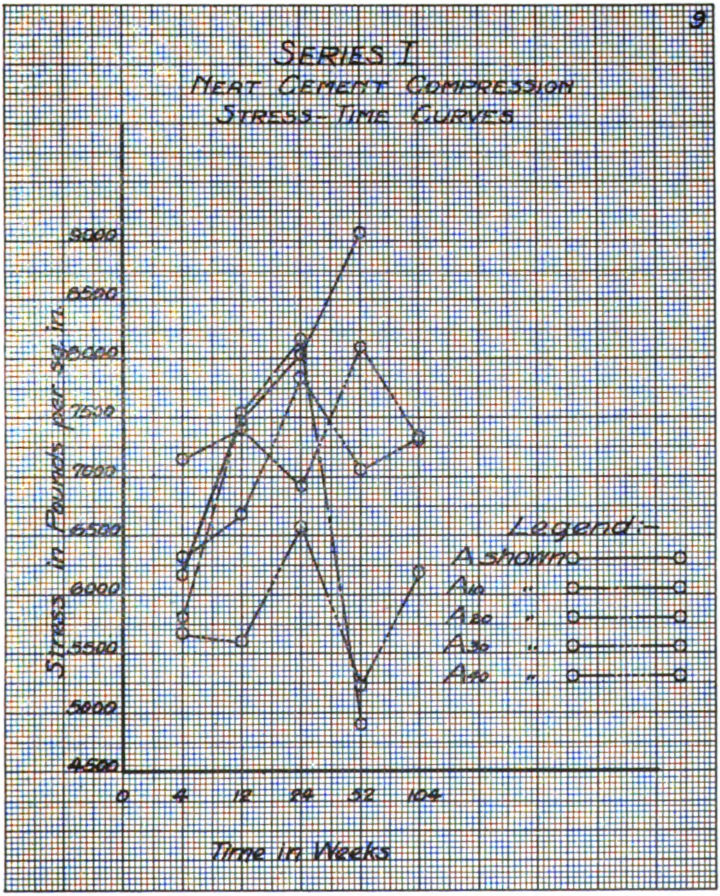

9
SERIES I
NEAT CEMENT COMPRESSION
STRESS-TIME CURVES
Stress in Pounds per sq. in.
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
0
4
12
24
52
104
Time in Weeks
Legend:-
A shown
A_{10} "
A_{20} "
A_{30} "
A_{50} "

TABLE IX

Series I

RELATIVE STRENGTHS

Age of test in weeks	4	12	24	52
A	3	2	2	1
A_{10}	4	1	1	5
A_{20}	1	3	4	2
A_{30}	2	4	3	3
A_{40}	5	5	5	4

Up to the 52-week tests, A_{10} has developed the highest average relative strength; A, second; A_{20}, third; A_{30}, fourth; and A_{40}, fifth, although the first four classifications are not consistently defined. Inclusive of the 52-week tests the relative classification gives Cement "A" first rank; A_{20}, second; A_{10}, third; A_{30}, fourth; and A_{40}, fifth. No direct comparison can be made for the 104-week tests, as the "A" specimens were lost, but in view of the very great drop in the A_{10} specimens it appears that the final rank should be A, A_{20}, A_{30}, A_{40}, and A_{10} last.

Curve Sheet 10 is similar to Curve Sheet 9, except that the results plotted are for Lehigh Portland Cement "B" and blended cements of the same. (See Table C, Appendix A.) Here again many inconsistencies seem to exist; the tests of Cement "B" show marked variation in strength, it having attained a maximum strength at twelve weeks with an accompanying falling off of about 2500 pounds at the 24-week test-period. B_{10} develops an unusual strength at twelve weeks, but this is not maintained at the later period of testing. This cement develops a very satisfactory average strength throughout the period of testing. B_{20} develops very satisfactory strengths up to and including 24 weeks; but the 52-week test is unusually low. This 52-week test gave results, however, which are sufficiently uniform in range to warrant their acceptance and therefore no check tests were run. B_{30} is similar to B_{20}, the average results being somewhat higher. B_{40} seems to give the most consistent results of any of the cements in this series in point of range in strength developed, although its average strength is the lowest. The average strength of B_{40} is about 6400 pounds per square inch over the entire period of testing. Table X is similar to Table IX.

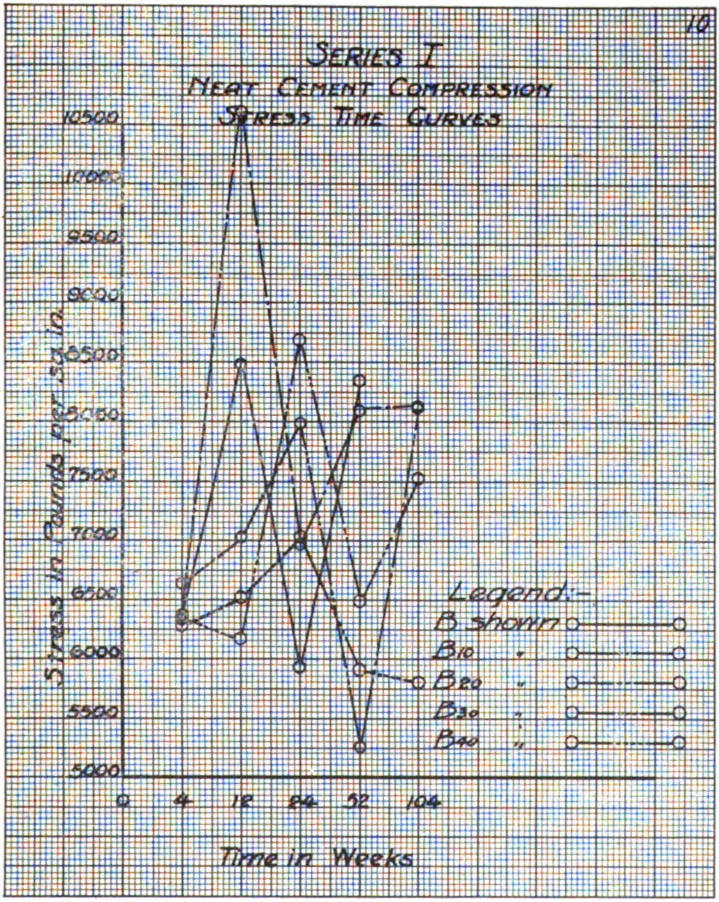

10
SERIES I
NEAT CEMENT COMPRESSION
STRESS TIME CURVES
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
Stress in Pounds per sq. in.
0
4
12
24
52
104
Time in Weeks
Legend:-
B shown
B10 "
B20 "
B30 "
B40 "

TABLE X

Series I

RELATIVE STRENGTHS

Age of test in weeks	4	12	24	52
B	3	2	5	1
B_{10}	2	1	3	2
B_{20}	1	3	2	5
B_{30}	3	5	1	3
B_{40}	5	4	4.	4

In point of relative strength B_{10} seems to rank first. Since "B" and B_{20} have the same relative strengths during the entire period of testing, there is but little preference between them for second relative rank. B_{30} assumes fourth place, and B_{40}, fifth; this distinction, however, is not well defined; in point of excellence there seems to be but little real preference between cements B, B_{10}, B_{20}, and B_{30}. B_{40} is on the average probably somewhat inferior in strength to the others, but this inferiority is not pronounced.

The "B" specimens for 104 weeks were lost, and hence no comparison is made for this age.

Curve Sheet 11 is similar to 9, differing only in the commercial cements used. The results here plotted are those obtained from tests of Red Ring Portland Cement "C" and blended cements of the same. (See Table C, Appendix A.) Were it not for the high strength attained at the 24-week period by Cement C_{20}, the curves here shown might seem to indicate that the various cements behave in a more or less uniform manner. The maximum strength in each case was developed at 24 weeks, with an accompanying falling off in strength at the test period of 52 weeks, increasing again for the 104-week tests.

TABLE XI

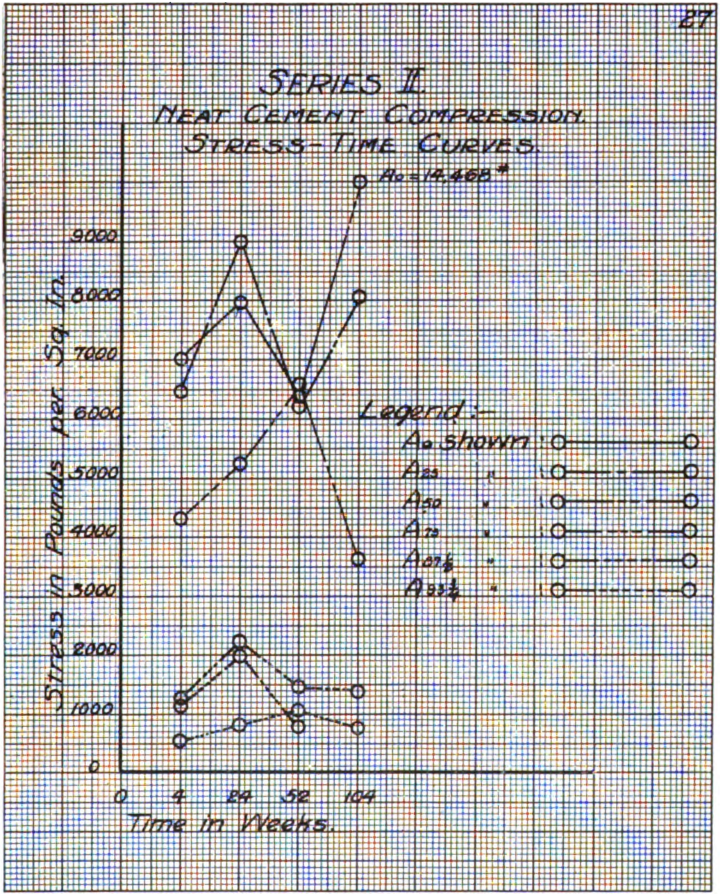
Series I

RELATIVE STRENGTHS

Age of test in weeks	4	12	24	52	104
C	4	1	3	2	1
C_{10}	2	2	4	4	2
C_{20}	1	5	2	3	3
C_{30}	3	3	1	1	4
C_{40}	5	4	5	5	5

(D) Neat Cement In Compression.

Curve Sheet number 27 shows the results obtained by testing neat cement specimens of Division A in compression. (See Table G, Appendix A.) There is much the same irregularity to be observed in this series as in Series I, as for example the drop in the A_0 line from 24 to 52 weeks, its extremely high value at 104 weeks, the unusually high value of A_{25} at 24 weeks, and the large drop of the A_{50} line from 52 to 104 weeks.



As noted under Series I, this test is not a standard test, and hence no direct criterion exists by which to judge re-

Series 1

RESULTS OF COMPRESSION TESTS.

Tested at age of 12 weeks.

(Mortar Specimens)

Series Number	Spec's made 1916 Date	Dimensions				Weight		Load		Stress	
		Height inches	Diam. inches	Area in Sq. in.	Vol. in Cu. in.	Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.10	2.05	3.30	6.93	257	37.10	17220	17220	5220	5220
A	2-23	2.08	1.95	2.98	6.20	237	38.23	13510	13510	4540	4540
	-	2.11	2.02	3.20	6.75	256	37.92	16540	16540	5170	5170
Avr.	-							15757	15757	4980	4980
	-	2.07	2.02	3.20	6.62	254	38.37	12080	12080	3780	3780
B	2-23	2.10	2.01	3.17	6.66	251	37.70	12810	12810	4010	4040
	-	2.10	2.04	3.27	6.87	258	37.56	10600	10600	3380	3380
Avr.	-							11830	11830	3730	3730
	-	2.08	1.99	3.11	6.47	247	38.19	14690	14690	4720	4720
C	2-26	2.10	2.02	3.20	6.72	255	37.94	14980	14980	4680	4680
	-	2.13	2.00	3.14	6.68	262	39.23	16000	16000	5100	5100
Avr.	-							15223	15223	4830	4830
	-	2.02	2.01	3.17	6.41	240	37.44	8190	8190	2580	2580
A_{10}	2-26	2.03	2.00	3.14	6.38	239	37.46	14560	14560	4630	4630
	-	2.04	1.98	3.08	6.28	235	37.42	11460	11460	3720	3720
Avr.	-							11400	11400	3640	3640
	-	2.04	2.04	3.27	6.67	247	37.06	11730	11730	3590	3590
B_{10}	2-26	2.02	1.97	3.05	6.16	236	38.30	15420	15420	5070	5070
	-	2.03	2.04	3.27	6.64	247	37.23	12070	12070	3690	3640
Avr.	-							13073	13073	4120	4120
	-	2.11	2.02	3.20	6.75	254	37.83	12810	12810	4010	4010
C_{10}	2-26	2.10	2.02	3.20	6.72	253	37.64	8690	8690	2710	2710
	-	2.10	2.02	3.20	6.72	252	37.51	10310	10310	3220	3220
Avr.	-							10603	10603	3310	3310
	-	2.10	2.02	3.20	6.72	252	37.51	13750	13750	4300	4300
A_{20}	2-28	2.09	1.99	3.11	6.50	242	37.22	13300	13300	4280	4280
	-	2.08	1.99	3.11	6.47	242	37.41	11640	11640	3740	3740
Avr.	-							12897	12897	4110	4110
	-	2.10	2.03	3.23	6.78	258	38.08	10740	10740	3330	3330
B_{20}	2-28	2.07	1.98	3.08	6.38	237	37.16	10560	10560	3430	3430
	-	2.10	2.02	3.20	6.72	253	37.64	10310	10310	3220	3220
Avr.	-							10537	10537	3330	3330
	-	2.05	2.00	3.14	6.44	238	36.96	10030	10030	3200	3200
C_{20}	2-28	2.10	2.02	3.20	6.72	253	37.64	10080	10080	3150	3150
	-	2.06	1.98	3.08	6.35	240	37.80	9920	9920	3220	3220
Avr.	-							10010	10010	3190	3190
	-	2.08	2.00	3.14	6.53	240	36.77	9270	9270	2950	2950
A_{30}	3-1	2.12	2.01	3.27	6.93	255	36.82	10930	10930	3350	3350
	-	2.04	2.00	3.14	6.41	256	39.94	9780	9780	3110	3110
Avr.	-							9993	9993	3140	3140
	-	2.10	2.00	3.14	6.60	252	38.17	8960	8960	2850	2850
B_{30}	3-1	2.08	1.99	3.11	6.47	241	37.26	11180	11180	3590	3590
	-	2.08	1.99	3.11	6.47	240	37.08	9490	9490	3050	3050
Avr.	-							9877	9877	3160	3160
	-	2.08	1.98	3.08	6.41	236	36.82	9920	9920	3220	3220
C_{30}	3-1	2.07	1.98	3.08	6.38	239	37.46	9930	9930	3220	3220
	-	2.10	2.02	3.20	6.72	254	37.79	9370	9370	2930	2930
Avr.	-							9740	9740	3120	3120
	-	2.10	1.98	3.08	6.47	237	36.64	6990	6990	2270	2270
A_{40}	3-3	2.10	2.02	3.20	6.72	249	37.04	9500	9500	2970	2970
	-	2.10	2.00	3.14	6.60	248	37.58	9820	9820	3120	3120
Avr.	-							8770	8770	2790	2790
	-	2.10	2.00	3.14	6.60	240	36.38	5960	5960	1900	1900
B_{40}	3-3	2.08	2.00	3.14	6.53	243	37.23	6560	6560	2090	2090
	-	2.08	2.00	3.14	6.53	241	36.92	7110	7110	2260	2260
Avr.	-							6543	6543	2080	2080
	-	2.10	2.00	3.14	6.60	237	35.92	7870	7870	2500	2500
C_{40}	3-3	2.05	1.98	3.08	6.32	236	37.39	9040	9040	2930	2930
	-	2.05	1.98	3.08	6.32	232	36.70	5770	5770	1870	1870*
Avr.	-							7560	7560	2433	2433
		Average of Averages.									
A - B - C										4510	4510
A_{10} - B_{10} - C_{10}										3690	3690
A_{20} - B_{20} - C_{20}										3540	3540
A_{30} - B_{30} - C_{30}										3140	3140
A_{40} - B_{40} - C_{40}										2101	2101
		Average of Highest Breaks.									
A - B - C										4790	4790
A_{10} - B_{10} - C_{10}										4570	4570
A_{20} - B_{20} - C_{20}										3660	3660
A_{30} - B_{30} - C_{30}										3390	3390
A_{40} - B_{40} - C_{40}										2770	2770

*Chip off of end.

Series I

RESULTS OF COMPRESSION TESTS.

Tested at age of 24 weeks.

(Mortar Specimens)

Serial Number	Spec's made 1916 Date	Dimensions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	lb./sq. in. Ult.
	-	2.11	2.01	3.17	6.69	258	38.57	13730	15890	4330	5020
A	2-23	2.08	2.04	3.27	6.80	257	37.83	10290	11060	3150	3380
	-	2.12	2.01	3.17	6.72	259	38.52		12710		4020
Avr.	-							12010	13220	3740	4140
	-	2.12	2.03	3.23	6.85	254	37.08	13480	13480	4180	4180
B	2-23	2.10	2.04	3.27	6.87	252	36.66		17280		5500†
	-	2.08	1.97	3.05	6.35	249	39.22	11280	11770	3700	3860*
Avr.	-							13480	15380	4180	4840
	-	2.11	2.00	3.14	6.63	247	37.24	13180	13180	4200	4200
C	2-26	2.09	2.00	3.14	6.57	244	37.16	11150	11150	3550	3550
	-	2.11	2.02	3.20	6.75	256	37.94		13490		4220
Avr.	-							12165	12607	3870	3990
	-	2.06	1.98	3.08	6.35	236	37.20	12370	12370	4020	4020
A_{10}	2-26	2.12	2.02	3.20	6.78	255	37.60	14410	14410	4510	4510
	-	2.12	2.03	3.23	6.85	256	37.39	14630	14630	4530	4530
Avr.	-							13803	13803	4350	4350
	-	2.10	2.00	3.14	6.60	245	37.10	14000	14000	4460	4460
B_{10}	2-26	2.07	2.05	3.30	6.83	249	36.48	9390	9390	2840	2840
	-	2.06	2.05	3.30	6.80	246	36.18	14010	14010	4250	4250
Avr.	-							12467	12467	3850	3850
	-	2.10	2.03	3.23	6.78	252	37.14	8340	8340	2580	2580
C_{10}	2-26	2.11	2.04	3.27	6.90	252	36.52	15230	15230	4660	4660†
	-	2.10	1.99	3.11	6.54	241	36.87	13380	13380	4310	4310§
Avr.	-							12317	12317	3850	3850
	-	2.11	2.05	3.30	6.96	257	36.94	13660	13660	4140	4140
A_{20}	2-28	2.07	2.00	3.14	6.50	242	37.24	12160	12160	3870	3870
	-	2.10	2.00	3.14	6.60	242	36.70	8310	8750	2640	2780
Avr.	-							11377	11523	3550	3600
	-	2.09	2.00	3.14	6.57	240	36.53	9080	9080	2890	2890
B_{20}	2-28	2.12	2.02	3.20	6.78	253	37.30	7810	8170	2440	2550
	-	2.11	2.05	3.30	6.96	255	36.66	10020	10020	3040	3040
Avr.	-							8970	9090	2790	2830
	-	2.08	1.99	3.11	6.48	237	36.58	8100	8100	2600	2600
C_{20}	2-28	2.07	1.99	3.11	6.45	238	36.90	4200	6410	1350	2060
	-	2.08	2.05	3.30	6.87	252	36.66	9120	9120	2760	2760
Avr.	-							7140	7877	2240	2470
	-	2.08	2.05	3.30	6.87	255	37.12	10530	11690	3190	3540
A_{30}	3-1	2.07	2.02	3.20	6.63	242	36.50	6560	7700	2040	2400
	-	2.10	2.04	3.27	6.87	256	37.30	10540	10540	3230	3230
Avr.	-							9210	9977	2820	3060
	-	2.00	1.99	3.11	6.22	216	34.72	5650	7820	1820	2510¶
B_{30}	3-1	2.11	2.02	3.20	6.75	251	37.20	8090	8090	2590	2530
	-	2.12	2.04	3.27	6.93	253	36.52	12560	12560	3840	3840‡
Avr.	-							10325	10325	3250	3250
	-	2.11	2.02	3.20	6.75	254	37.66	12070	12070	3770	3770‡
C_{30}	3-1	2.09	1.97	3.05	6.38	237	37.14	6380	7500	2090	2450
	-	2.10	2.00	3.14	6.60	248	37.58	10690	10690	3490	3490
Avr.	-							9713	10087	3120	3240
	-	2.12	2.01	3.17	6.72	244	36.32	5260	5560	1660	1750
A_{40}	3-3	2.09	2.00	3.14	6.57	235	35.77	8910	8910	2840	2840
	-	2.11	2.04	3.27	6.90	252	36.52	9750	9750	2980	2980
Avr.	-							7973	8073	2490	2520
	-	2.13	2.00	3.14	6.69	242	36.18	9220	9220	2930	2930
B_{40}	3-3	2.14	2.04	3.27	6.72	255	37.96	7430	7430	2270	2270
	-	2.14	2.00	3.14	6.72	242	36.00	6420	6420	2040	2040‖
Avr.	-							7690	7690	2410	2410
	-	2.14	2.03	3.23	6.92	255	36.88	7500	7500	2320	2320‖
C_{40}	3-3	2.11	2.04	3.27	6.90	251	36.40	6570	6570	2010	2010*
	-	2.12	2.04	3.27	6.93	254	36.66	6660	6660	2040	2040*
Avr.	-							6660	6660	2040	2040
Average of Averages.											
A - B - C										3930	4320
A_{10} - B_{10} - C_{10}										4020	4020
A_{20} - B_{20} - C_{20}										2860	2970
A_{30} - B_{30} - C_{30}										3060	3180
A_{40} - B_{40} - C_{40}										2310	2320
Average of Highest Breaks.											
A - B - C										4240	4910
A_{10} - B_{10} - C_{10}										4550	4550
A_{20} - B_{20} - C_{20}										3310	3310
A_{30} - B_{30} - C_{30}										3610	3720
A_{40} - B_{40} - C_{40}										2770	2740

†Failed with report. *Chip off of base. Omit. §Failed with slight report.
‡Failed with light report. ‖Bad end. Omit. ¶Cavity in base. Omit.

Series I

RESULTS OF COMPRESSION TESTS.

Tested at age of 52 weeks.

(Mortar Specimens)

Serial Number	Spec's made 1916 Date	Dimensions				Weight		Load		Stress	
		Height inches	Diam. inches	Area in sq. In	Vol. in cu. in.	Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.05	2.05	3.30	6.77	258	38.1	12570	12570	3809	3809
A	2-23	2.05	2.00	3.14	6.44	241	37.4	10380	10380	3304	3304
	-	2.07	2.00	3.14	6.50	260	40.0	15890	15890	5056	5056
Avr.	-							12946	12946	4056	4056
	-	2.05	2.00	3.14	6.44	244	37.9	12110	12110	3859	3859
B	2-23	2.04	2.00	3.14	6.41	238	37.1	11000	13000	3502	4140
	-	2.03	2.00	3.14	6.37	237	37.2	8000	10210	2547	3252
Avr.	-							10370	11773	3303	3750
	-	2.04	2.00	3.14	6.41	246	38.4	12000	13650	3822	4350
C	2-26	2.04	2.00	3.14	6.41	245	38.2	10000	11850	3180	3772
	-	2.02	2.02	3.21	6.48	248	38.3	15000	15770	4672	4912
Avr.	-							12333	13757	4225	4345
	-	2.00	2.00	3.14	6.28	257	40.9	11500	11890	3660	3782
A_{10}	2-26	2.04	2.00	3.14	6.41	239	37.3	11550	11550	3678	3679
	-	2.00	2.00	3.14	6.28	260	41.4	12000	12000	3821	3820
Avr.	-							11683	11813	3720	3760
	-	2.08	2.00	3.14	6.53	246	37.7	13000	13600	4138	4331
B_{10}	2-26	2.05	2.02	3.21	6.58	248	37.7	10600	10680	3300	3327
	-	2.00	1.93	2.93	5.86	238	40.7	14500	14500	4950	4948
Avr.	-							12700	12927	4129	4202
	-	2.10	2.00	3.14	6.59	256	38.9	9506	9500	3240	3025
C_{10}	2-26	2.06	2.00	3.14	6.47	256	39.6	14200	14250	4540	4537
	-	2.05	2.00	3.14	6.43	242	37.6	10800	10800	3440	3440
Avr.	-							11500	11517	3740	3667
	-	2.12	2.00	3.14	6.66	256	38.4	8000	11970	2548	3812
A_{20}	2-28	2.12	2.00	3.14	6.66	255	38.3	12860	12860	4068	4069
	-	2.04	2.04	3.27	6.67	259	38.8	13000	14120	3976	4320
Avr.	-							11287	12983	3531	4067
	-	2.05	2.00	3.14	6.43	254	39.5	8000	9940	2547	3166
B_{20}	2-28	2.04	2.00	3.14	6.40	252	39.4	11500	11680	3661	3720
	-	2.05	2.00	3.14	6.43	255	39.7	11610	11610	3700	3700
Avr.	-							10370	11077	3303	3529
	-	2.08	2.00	3.14	6.53	244	37.4	6200	6860	1973	2184
C_{20}	2-28	2.05	2.02	3.21	6.58	257	39.1	9000	9260	2810	2884
	-	2.02	2.02	3.21	6.48	255	39.3	8500	8800	2647	2740
Avr.	-							7900	8307	2477	2607
	-	2.10	2.00	3.14	6.59	257	39.0	7000	7100	2228	2260
A_{30}	3-1	2.04	1.98	3.08	6.28	239	38.1	10100	10470	3279	3398
	-	2.07	2.04	3.27	6.77	258	38.1	7260	7260	2220	2220
Avr.	-							8120	8277	2576	2626
	-	2.07	2.00	3.14	6.50	244	37.6	5500	5760	1751	1834
B_{30}	3-1	2.07	2.04	3.27	6.77	257	38.0	8740	8740	2673	2672
	-	2.06	2.00	3.14	6.47	244	37.7	10260	10260	3268	3268
Avr.	-							8166	8253	2564	2591
	-	2.06	2.00	3.14	6.47	256	39.6	6400	6400	2039	2039
C_{30}	3-1	2.04	2.00	3.14	6.41	252	39.3	8470	8970	2857	2857
	-	2.05	2.00	3.14	6.43	251	39.1	6740	6740	2140	2144
Avr.	-							7203	7370	2345	2347
	-	2.05	1.98	3.08	6.31	239	37.9	6120	6260	1987	2032
A_{40}	3-3	2.10	2.00	3.14	6.59	253	38.4	9290	9340	2957	2975
	-	2.08	2.00	3.14	6.53	240	36.8	8425	8425	2681	2680
Avr.	-							7945	8008	2542	2562
	-	2.10	2.00	3.14	6.59	252	38.2	5980	5980	1904	1904
B_{40}	3-3	2.10	2.00	3.14	6.59	246	37.4	5870	5870	1870	1870
	-	2.10	2.00	3.14	6.59	252	38.2	7000	7100	2230	2260
Avr.	-							6283	6317	2001	2011
	-	2.08	2.00	3.14	6.53	251	38.5	6000	6430	1910	2047
C_{40}	3-3	2.10	2.00	3.14	6.59	249	37.8	4480	4480	1428	1428
	-	2.11	2.00	3.14	6.62	250	37.8	7170	7170	2282	2282
Avr.	-							5883	6027	1873	1919
Average of Averages.											
A - B - & C										3860	4050
A_{10} - B_{10} & C_{10}										3863	3876
A_{20} - B_{20} & C_{20}										3104	3401
A_{30} - B_{30} & C_{30}										2495	2521
A_{40} - B_{40} & C_{40}										2139	2164
Average of Highest Breaks.											
A - B & C										4529	4703
A_{10} - B_{10} & C_{10}										4468	4435
A_{20} - B_{20} & C_{20}										3526	3641
A_{30} - B_{30} & C_{30}										9404	3174
A_{40} - B_{40} & C_{40}										2490	2506

Series I

RESULTS OF COMPRESSION TESTS.

Tested at age of 104 weeks.

(Mortar Specimens)

Serial	Spec's made 1916 Date	Dimension		Area in sq. in	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.10	2.04	3.27	6.87	261	37.99	11200	17880	3425	5467
A	2-23	2.10	1.96	3.02	6.34	239	37.70	8570	8730	2838	2891
	-	2.05	1.98	3.08	6.31	243	38.51	8970	9640	2912	3130
Avr.	-							9580	12083	3058	3830
	-	2.09	2.04	3.27	6.83	258	37.77	9350	10110	2859	3092
A_{10}	2-26	2.08	2.04	3.27	6.70	260	38.80	8550	12200	2615	3731
	-	2.11	2.00	3.14	6.62	260	39.29	8000	8400	2548	2675
Avr.	-							8633	10237	2674	3166
	-	2.14	2.02	3.20	6.85	256	37.37	11960	11960	3738	3738
A_{20}	2-28	2.11	1.98	3.08	6.50	249	38.31	8310	8310	2698	2698
	-	2.12	2.02	3.20	6.78	261	38.50	8050	9540	2516	2981
Avr.	-							9440	9937	2984	3139
	-	2.11	2.04	3.27	6.90	258	37.39	7250	7250	2217	2217
A_{30}	3-1	2.15	2.05	3.30	7.10	262	36.90	6370	6370	1930	1930
	-	2.06	1.96	3.02	6.22	240	38.58	10030	10030	3321	3321
Avr.	-							7883	7883	2489	2489
	-	2.10	2.01	3.17	6.65	247	37.14	5920	5920	1868	1868
A - $_{40}$	3-3	2.10	2.01	3.17	6.65	254	38.20	7540	7540	2378	2378
	-	2.10	2.01	3.17	6.65	254	38.20	7160	7160	2259	2259
Avr.	-							6873	6873	2168	2168
	-										
B	2-23										
	-										
Avr.	-										
	-										
	-	2.05	1.98	3.08	6.31	235	37.24	5970	6600	1938	2143
B_{10}	2-26	2.05	1.95	2.98	6.11	237	38.79	12150	12970	4077	4352
	-	2.07	1.98	3.08	6.38	235	36.74	10500	10600	3409	3442
Avr.	-							9540	10057	3141	3312
	-	2.13	2.01	3.17	6.75	258	38.22	9040	10210	2852	3221
B_{20}	2-28	2.08	1.96	3.02	6.28	242	38.54	11270	11270	3732	3732
	-	2.07	1.97	3.05	6.31	242	38.35	9440	9440	3095	3095
Avr.	-							9917	10307	3226	3349
	-	2.13	1.99	3.11	6.62	245	37.01	8930	8930	2871	2871
B_{30}	3-1	2.10	1.98	3.08	6.47	244	37.71	6570	7300	2133	2370
	-	2.11	1.98	3.08	6.50	246	37.85	7550	7550	2451	2451
Avr.	-							7683	7927	2485	2564
	-	2.10	1.98	3.08	6.47	239	36.94	9080	9080	2948	2948
B_{40}	3-3	2.12	1.98	3.08	6.53	242	37.06	8780	8780	2851	2851
	-	2.15	2.02	3.20	6.88	249	36.19	8140	8140	2531	2531
Avr.	-							8667	8667	2777	2777
	-	2.10	1.97	3.05	6.40	236	36.88	15890	15890	5210	5210
C	2-26	2.10	1.97	3.05	6.40	240	37.50	19960	19960	6544	6544
	-	2.10	1.97	3.05	6.40	239	37.34	14240	14240	4669	4669
Avr.	-							16697	16697	5474	5474
	-	2.09	1.97	3.05	6.37	243	38.15	7800	8350	2557	2738
C_{10}	2-26	2.09	1.97	3.05	6.37	240	37.68	11570	11570	3793	3793
	-	2.10	2.02	3.20	6.72	255	37.95	7300	8490	2281	2653
Avr.	-							8890	9470	2877	3061
	-	2.10	2.02	3.20	6.72	257	38.24	7970	7930	2491	2478
C_{20}	2-28	2.06	2.00	3.14	6.47	239	36.94	7360	7360	2344	2344
	-	2.10	2.02	3.20	6.72	256	38.10	7730	7730	2416	2416
Avr.	-							7687	7673	2417	2413
	-	2.10	1.98	3.08	6.47	241	37.25	6780	6780	2201	2201
C_{30}	3-1	2.12	2.01	3.17	6.72	249	37.05	4280	4560	1350	1438
	-										
Avr.	-							5530	5670	1776	1819
	-	2.08	1.99	3.11	6.47	238	36.78	7240	7240	2328	2328
C_{40}	3-3	2.08	1.99	3.11	6.47	239	36.94	6840	6840	2199	2199
	-										
Avr.	-							7040	7040	2264	2264
Average of Averages.											
A - C											4652
A_{10}, B_{10}, C_{10}											3180
A_{20}, B_{20}, C_{20}											2967
A_{30}, B_{30}, C_{30}											2291
A_{40}, B_{40}, C_{40}											2403

Series II

RESULTS OF TENSION TESTS.

(Neat Specimens)

Serial Number	Spec's made 1916 Date	24 hours	1 week	4 weeks	8 weeks	12 weeks	24 weeks	52 weeks	104 weeks
	-	424	696	618	785	700	705	645	707
A_0	6-1	407	632	842	701	695	710	610	
	-	349	728	709	749	794	880	565	
Avr.	-	393+	685	776	745	730	765	607	707
	-	327	563	618	611	630	652	685	737
A_{25}	6-2	304	486	527	648	617	675	500	591
	-	332	635	636	587	686	561	705	620
Avr.	-	321	599	627	615	644	629	630	649
	-	210	442	562	569	553	540	520	655
A_{50}	6-2	235	416	584	558	492	590	610	520
	-	293	435	599	574	628	500	575	640
Avr.	-	246	431	582	567	558	543	568	605
	-	61	120	231	276	272	220		
A_{75}	6-15	60	170	233	224	298	237		
	-	28	136	94	228	278	334		
Avr.	-	60+	153	232	242	283	263		
	-		124	230		215	243	230	370
$A_{87\,1/2}$	7-10		107	278		275	312	277	335
	-		118	247		256	288	222	320
Avr.	-		116	252		249	281	243	342
	-		84	167	185	No	236	210	55
$A_{93\,3/4}$	7-12		76	165	167	No	244	206	135
	-		62	147	182	No	201	245	
Avr.	-		74	160	178	No	227	220	95
	-		No			No	00		30
$A_{96\,7/8}$	8-8		No			No	30		
	-		No			No	26		
Avr.	-		No			No	28		30
	-	67	261	410	470	355	311	455	
A_{75}*	8-11	57	238	372	411	395	338	476	
Special	-	66		392		405	289		
Avr.	-	63	250	391	441	385	313	465	
	-	397	729	396	828	730	754	720	770
B_0	8-9	428	690	760	755	635	730	727	795
	-	448	650	835	771	807	560	642	760
Avr.	-	424	690	664	785	724	681	696	775
	-	422	581	653	560	696	807	725	698
B_{25}	8-10	378	637	775	715	752	639	685	708
	-	389	584	686	730	649	659	710	685
Avr.	-	396	601	705	668	699	701	707	697
	-	219	456	578	605	580	560	635	615
B_{50}	8-11	181	460	550	598	593	595	625	645
	-	206	461	596	570	500	560	589	645
Avr.	-	202	459	575	591	558	572	616	635
	-	29	240	375	461	432	456	482	495
B_{75}	8-14	59	259	430	445	510	491	482	482
	-	64	255	380	523	427	421	450	505
Avr.	-	51	251	395	476	456	456	471	494
	-	No	92	220	243	265	271	290	303
$B_{87\,1/2}$	8-15	No	102	206	259	256	278	262	300
	-	No	101	226	237	233	285	320	350
Avr.	-	No	98	217	246	251	278	291	318
	-	No	70	128	206	189	218	256	180
$B_{93\,3/4}$	8-15	No	73	150	194	220	234	272	
	-	No	70	165	180	209	221	263	
Avr.	-	No	71	144	193	206	224	264	180
	-	No	No	45	No	No	33	40	45
$B_{96\,7/8}$	8-16	No	No	21	No	No	42	81	70
	-	No	No	21	No	No	52	85	
Avr.	-	No	No	29	No	No	42	69	57
Average of Averages.									
A_0 - B_0		408	687	720	765	727	723	652	741
A_{25} - B_{25}		358	600	666	641	671	665	668	673
A_{50} - B_{50}		224	445	578	579	558	558	592	620
A_{75} - B_{75}		56	202	314	359	369	359		
$A_{87\,1/2}$ - $B_{87\,1/2}$			107	235		250	279	267	330
$A_{93\,3/4}$ - $B_{93\,3/4}$			73	152	186		225	242	137
Average of Highest Breaks.									
A_0 - B_0		436	728	839	807	801	817	686	751
A_{25} - B_{25}		377	636	706	689	719	741	715	723
A_{50} - B_{50}		256	452	598	589	611	593	622	650
A_{75} - B_{75}		62	215	332	399	404	413		
$A_{87\,1/2}$ - $B_{87\,1/2}$			113	252		270	299	298	360
$A_{93\,3/4}$ - $B_{93\,3/4}$			79	166	190		239	258	157

Series II

RESULTS OF TENSION TESTS.

(Mortar Specimens)

Serial Number	Date made 1916 Date	1 week	4 weeks	8 weeks	12 weeks	24 weeks	52 weeks	104 weeks
	-	306	390	476	442	467	405	415
A_0	6-1	291	415	491	511	477	420	414
	-	295	423	379	470	435	375	426
Avr.	-	297+	409	484	474	459	400	418
	-	282	377	440	373	403	395	410
A_{25}	6-2	280	353	464	458	385	400	370
	-	256	420	395	405	414	420	432
Avr.	-	273	383	433	412	401	405	407
	-	216	301	342	380	410	325	345
A_{50}	6-2	208	310	394	393	416	345	418
	-	203	262	355	368	395	362	385
Avr.	-	209	291	364	380	407	344	383
	-	99	185	239	267	262	275	300
A_{75}	6-15	106	192	241	304	262	270	260
	-	92	187	226	262	290	300	
Avr.	-	99	188	235	278	271	282	280
	-	36	53		75	84	85	
$A_{87\,1/2}$	7-10	26	56		83	92	77	
	-		60		83	104	100	70
Avr.	-	31	56		80	93	87	70
	-	No	No	No	No	No		
$A_{93\,3/4}$	7-12	No	No	No	No	No		
	-	No	No	No	No	No		
Avr.	-	No	No	No	No	No		
	-	No	No					
$A_{96\,7/8}$	8-8	No	No					
	-	No	No					
Avr.	-	No	No					
	-	264	381	400	412	400	350	430
B_0	8-9	197	347	341	412	455	285	405
	-	242	393	465	452	468	355	370
Avr.	-	253	374	432	425	441	330	402
	-	270	354	385	345	383	399	308
B_{25}	8-10	279	319	365	357	424	362	386
	-	265	311	307	377	363	308	310
Avr.	-	271	328	352	360	390	356	335
	-	120	205	255	297	283	315	275
B_{50}	8-11	140	190	295	263	303	307	255
	-	136	227	265	264	335	300	275
Avr.	-	132	207	272	275	307	307	268
	-	69	147	178	183	178	245	210
B_{75}	8-14	62	145	164	210	194	215	240
	-	64	144	165	174	218	193	
Avr.	-	64	145	169	189	197	218	225
	-	No	73	86	107	137	142	115
$B_{87\,1/2}$	8-15	No	52	87	106	132	127	110
	-	No	35	79	85	106	165	80
Avr.	-	No	62	84	100	125	145	102
	-	No	No	No	63	88	98	
$B_{93\,3/4}$	8-15	No	No	No	40	62	63	90
	-	No	No	No	52	64	85	
Avr.	-	No	No	No	52	71	82	90
	-	No	No					
$B_{96\,7/8}$	8-16	No	No					
	-	No	No					
Avr.	-	No	No					
Average of Averages.								
A_0 - B_0		274	392	458	449	450	365	410
A_{25} - B_{25}		272	355	392	386	395	380	371
A_{50} - B_{50}		170	249	318	328	357	326	325
A_{75} - B_{75}		82	166	202	233	234	250	252
$A_{87\,1/2}$ - $B_{87\,1/2}$		—	59	—	90	109	116	86
Average of Highest Breaks.								
A_0 - B_0		285	408	478	481	472	388	428
A_{25} - B_{25}		280	387	424	417	419	410	409
A_{50} - B_{50}		178	268	344	345	375	338	346
A_{75} - B_{75}		87	169	209	257	254	272	270
$A_{87\,1/2}$ - $B_{87\,1/2}$			66		95	120	132	92

Series II

RESULTS OF COMPRESSION TESTS.

		Stress in pounds ptr square inch							
Series Number	Specimen made	4 weeks Neat	4 weeks Mortar	24 weeks Neat	24 weeks Mortar	52 weeks Neat	52 weeks Mortar	104 weeks Neat	104 weeks Mortar
		8200	1954	5430	2535	8615	2548	13936	2095
A_0		7350	1623	9180	2500	6350	2070	14212	2255
		5490	2171	9350	2810	4140	2385	15256	2095
Av.		7013	1916	7987	2615	6368	2334	14468	2148
		7570	1918	7430	1910	8879	3274	8662	2950
B_0		6890	1571	7820	2020	8060	3869	9070	1735
		6150	1678	8780	2542	7293	3965	7910	
Av.		6870	1722	8010	2160	8077	3703	8547	2343
		6520	1765	7490	3000	6529	2045	8642	2900
A_{25}		5770	2218	10790	2670	5303	2468	8880	1685
		7140	1980	8740	2315	6768	2618	6637	
Av.		6477	1988	9007	2661	6200	2377	8053	2293
		6280	2090	6940	2050	7055	1720	5390	2148
B_{25}		6660	1974	7420	2020	7982	2270	5550	1313
		6350	1875	7525	2285	6864	2448		
Av.		6430	1980	7295	2115	7300	2146	5470	1733
		4450	1434	5300	2175	6019	2500	4025	1895
A_{50}		4370	1474	5120	2180	8089	1781	2381	815
		4130	1523	5300	2215	5662	2131	4435	
Av.		4317	1477	5240	2190	6590	2137	3614	1355
		3452	1028	4750	897	4373	730	4348	
B_{50}		4060	898	5620	955	6527	1152	5291	
		5140	889	6390	1700	7120	601	4340	
Av.		4217	938	5586	1195	6007	828	4660	
		1511		2300	1170	1392	965	1422	938
A_{75}		1292	824	2450	1221	1115	1076	1609	768
		1038	753	1893	1171	1895	771	1135	1010
Av.		1280	789	2214	1187	146[illegible]	937	1389	905
		1827	311	2460	335	1786	637	2249	508
B_{75}		2157	486	2620	480	2461	685	2543	507
		1776	503	2080	470	2338	503	2431	698
Av.		1920	431	2386	431	2195	608	2408	571
		1141	338	1862	534	1197	354		
$A_{87\,1/2}$		947	324	1873	420	398	573		
		1310	360	2240	589		637		
Av.		1133	340	1992	514	798	521		
		868	342	1055	382	1169	1340	1234	518
$B_{87\,1/2}$		782	311	1014	368	1115	929	1211	570
		814	272	1040	308	1227	1036		332
Av.		821	308	1036	353	1170	1102	1222	473
		531	No	746	68.7	924		781	No
$A_{93\,3/4}$		626	No	737	56.4	1010		810	No
		498	No	962.5	84.6	1290		705	No
Avr.		552	No	815	69.9	1075		765	No
		564	99	961	245	949	159	848	194
$B_{93\,3/4}$		648	71	946	194	639	153	1290	433
		338	59	795	161	982	252	1273	
Av.		517	76	901	202	857	188	1137	314
		No	No	31.9			No	No	
$A_{96\,7/8}$		No	No	25.3		19			
		No	No	43.0		25			
Av.		No	No	33.4		22	No	No	
		30	318	61.2		61	284	No	
$B_{96\,7/8}$		43	274	69.7		48		No	
		16	164	83.8		63			
Av.		29	252	71.5		57	284	No	
Average of Averages									
A_0 - B_0		6942	1819	7999	2388	7223	3019	11508	2245
A_{25} - B_{25}		6454	1984	8151	2388	6750	2262	4893	3882
A_{50} - B_{50}		4267	1208	5413	1693	5835	1483	4137	
A_{75} - B_{75}		1600	610	2300	809	1831	773	1899	738
$A_{87\,1/2}$ - $B_{87\,1/2}$		977	324	1514	434	984	820		
$A_{93\,3/4}$ - $B_{93\,3/4}$		535		858	136	966		951	
Average of Highest Breaks.									
A_0 - B_0		7885	2045	9065	2676	8747	3257	11959	2603
A_{25} - B_{25}		6900	2154	9158	2643	7375	2033	5514	4225
A_{50} - B_{50}		4795	1272	5845	1958	7605	1826	4863	
A_{75} - B_{75}		1834	664	2535	850	2178	880	2076	854
$A_{87\,1/2}$ - $B_{87\,1/2}$		1089	351	1648	486	1212	989		
$A_{93\,3/4}$ - $B_{93\,3/4}$		637		962	165	1136		1050	
$A_{96\,7/8}$ - $B_{96\,7/8}$								No	

For detailed results see Tables 17 to 24 inclusive.

Series II
RESULTS OF COMPRESSION TESTS.
Tested at age of 4 weeks.
(Neat Specimens)

Series Number	Spec's made 1916 Date	Dimensions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height	Diam.			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.00	1.97	3.05	6.10	224	36.71	10240	24420	3570	8200
A_0	6-8	2.03	2.01	3.17	6.44	240	37.29	13810	23340	4360	7350
	-	1.93	2.02	3.20	6.18	224	37.25	8240	17580	2575	5490
Avr.	-							10763	21780	3502	7013
	-	2.06	2.04	3.27	6.74	236	35.04	7470	21330	2285	6520
A_{25}	6-9	2.08	2.05	3.30	6.87	244	35.50	8890	19050	2694	5770
	-	2.05	2.04	3.27	6.70	240	35.80	6830	23380	2090	7140
Avr.	-							7730	21253	2356	6477
	-	2.02	2.00	3.14	6.34	215	33.91	9170	13990	2923	4450
A_{50}	6-12	2.05	1.98	3.08	6.32	218	34.49	5000	13490	1624	4370
	-	2.06	1.98	3.08	6.35	218	34.31	8800	12720	2855	4130
Avr.	-							7657	13400	2467	4317
	-	2.08	2.03	3.24	6.74	212	31.42	4900	4900	1511	1511
A_{75}	6-19	2.04	1.98	3.08	6.28	199	31.70	600	3980	195	1292
	-	2.04	2.00	3.14	6.40	199	31.11	2820	3260	898	1038
Avr.	-							2773	4047	868	1280
	-	2.12	2.06	3.34	7.07	220	31.11		3810		1141
$A_{87\,1/2}$	7-12	2.11	2.02	3.20	6.75	217	32.15	2640	3030	824	947
	-	2.11	2.00	3.14	6.62	210	31.72	3780	4110	1203	1310
Avr.	-							3210	3650	1014	1133
	-	2.12	2.02	3.20	6.78	215	31.72	1540	1700	481	531
$A_{93\,3/4}$	8-7	2.12	2.06	3.34	7.07	228	32.25		2030		626
	-	2.20	1.97	3.05	6.71	209	31.11	920	1520	302	498
Avr.	-							1230	1750	392	552
	-										No
$A_{96\,7/8}$	8-8										No
	-										No
Avr.	-										No
	-	2.10	2.08	3.40	7.14	256	35.88	21420	25770	6310	7570
B_0	8-9	2.04	2.05	3.30	6.74	239	35.45	21990	22760	6660	6890
	-	2.08	2.04	3.27	6.80	240	35.29	18690	20120	5720	6150
Avr.	-							20700	22883	6230	6870
	-	2.10	1.99	3.11	6.53	229	35.08	17670	19540	5680	6280
B_{25}	8-10	2.10	2.02	3.20	6.72	248	36.91	18300	21330	5720	6660
	-	2.07	1.99	3.11	6.44	229	35.59		19760		6350
Avr.	-							17985	20210	5700	6430
	-	2.08	1.98	3.08	6.41	224	34.92		10630		3452
B_{50}	8-11	2.08	2.02	3.20	6.66	233	34.95	12390	12980	3870	4060
	-	2.10	2.03	3.24	6.80	237	34.85		16620		5140
Avr.	-							12390	13410	8870	4217
	-	2.14	1.98	3.08	6.59	224	34.00	5250	5630	1705	1827
B_{75}	8-14	2.14	2.01	3.17	6.78	229	33.75		6840		2157
	-	2.08	2.02	3.20	6.66	219	32.85		5680		1776
Avr.	-							5250	6050	1705	1920
	-	2.08	2.04	3.27	6.80	224	32.94		2840		868
$B_{87\,1/2}$	8-15	2.10	2.08	3.40	7.14	230	32.20		2660		782
	-	2.08	2.09	3.43	7.14	231	32.35		2795		814
Avr.	-								2765		821
	-	2.14	2.00	3.14	6.71	216	32.20		1770		564
$B_{93\,3/4}$	8-15	2.10	2.05	3.30	6.94	220	31.70		2140		648
	-	2.12	2.02	3.20	6.78	216	31.85		1400		338
Avr.	-								1770		517
	-	2.08	1.97	3.05	6.34	209	32.97		90		30
$B_{96\,7/8}$	8-16	2.10	2.04	3.27	6.86	224	32.61		140		43
	-	2.05	2.00	3.14	6.43	206	32.05		50		16
Avr.	-								93		29
Average of Averages.											
A_0 - B_0										4866	6941
A_{25} - B_{25}										4028	6452
A_{50} - B_{50}										3169	4267
A_{75} - B_{75}										1286	1600
$A_{87\,1/2}$ - $B_{87\,1/2}$										1014	977
$A_{93\,3/4}$ - $B_{93\,3/4}$										392	535
Average of Highest Breaks.											
A_0 - B_0										5510	7885
A_{25} - B_{25}										4207	6900
A_{50} - B_{50}										8397	4795
A_{75} - B_{75}										1608	1834
$A_{87\,1/2}$ - $B_{87\,1/2}$										1208	1004
$A_{93\,3/4}$ - $B_{93\,3/4}$										481	637

Series II
RESULTS OF COMPRESSION TESTS.
Tested at age of 24 weeks.
(Neat Specimens)

Serial Number	Date made 1916	Dimensions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.00	1.96	3.02	6.04	226	37.40	11980	16385	3962	5430
A_0	6-8	2.00	1.97	3.05	6.10	229	37.50	20000	28000	6550	9180*
	-	1.98	1.97	3.05	6.04	231	38.23	23560	28550	7720	9350
Avr.	-							18513	24312	6077	7987
	-	2.06	2.01	3.17	6.54	236	36.10	17770	23790	5600	7490
A_{25}	6-9	2.04	2.02	3.20	6.55	244	37.25	9500	34520	2970	10790 *
	-	2.08	2.02	3.20	6.67	245	36.75	17980	27980	5620	8740
Avr.	-							15083	28763	4730	9007
	-	2.10	2.03	3.24	6.80	235	34.55	12370	17190	3815	5300
A_{50}	6-12	2.03	1.98	3.08	6.26	217	34.65	10000	15715	2248	5120
	-	2.06	1.98	3.08	6.35	221	34.80	13400	16320	4350	5300
Avr.	-							11923	16408	3471	5240
	-	2.10	2.04	3.27	6.87	217	31.60	7320	7520	2240	2300
A_{75}	6-19	2.05	1.98	3.08	6.32	206	32.60	7480	7540	2430	2450
	-	2.04	1.99	3.11	6.35	200	31.51	5890	5890	1893	1893
Avr.	-							6897	6983	2188	2214
	-	2.06	2.05	3.30	6.80	222	32.46	6150	6150	1862	1862
$A_{87\ 1/2}$	7-12	2.05	1.97	3.05	6.25	211	34.75	5720	5720	1873	1873 †
	-	2.06	2.00	3.14	6.48	210	32.40	7030	7030	2240	2240
Avr.	-							6300	6300	1992	1992
	-	2.10	2.00	3.14	6.60	217	32.90	2020	2340	650	746
$A_{93\ 3/4}$	8-7	2.09	1.99	3.11	6.50	220	33.85	2100	2290	675	737.0
	-	2.10	1.99	3.11	6.54	210	32.10	2800	2990	901	962.5
Avr.	-							2306	2540	742	815
	-	1.90	2.00	3.14	5.97	199	33.30	80	100	25.5	31.9
$A_{96\ 7/8}$	8-8	1.89	2.01	3.17	5.99	192	32.10	80	80	25.3	25.3
	-	2.00	2.00	3.14	6.28	197	31.39	90	135	28.6	43.0
Avr.	-							83	105	26.5	33.4
	-	2.07	2.04	3.27	6.77	245	36.20	17800	24320	5440	7430
B_0	8-9	2.08	2.03	3.24	6.74	243	36.10	16740	25360	5170	7820
	-	2.07	2.04	3.27	6.77	244	36 09	18300	28660	5590	8780
Avr.	-							17613	26113	5400	8010
	-	2.10	2.10	3.46	7.24	253	34.9	19000	24000	5480	6940
B_{25}	8-10	2.11	2.09	3.43	7.24	255	35.25	9500	25420	2770	7420
	-	2.10	2.09	3.43	7.21	251	34.80	14000	25830	4080	7525
Avr.	-							14166	25083	4110	7295
	-	2.04	2.04	3.27	6.68	239	35.79	9800	15530	2990	4750
B_{50}	8-11	2.04	2.04	3.27	6.68	237	35.50	11540	18370	3530	5620
	-	2.04	2.04	3.27	6.68	234	35.10	15000	20940	4580	6390
Avr.	-							12113	18280	3700	5586
	-	2.08	2.01	3.17	6.60	232	35.20	7500	7800	2370	2460
B_{75}	8-14	2.06	2.01	3.17	6.53	219	33.59	7000	8300	2210	2620
	-	2.00	2.04	3.27	6.54	219	33.59	6400	6800	1959	2080
Avr.	-							6966	7633	2179	2386
	-	2.08	2.08	3.40	7.07	222	31.40	3590	3590	1055	1055
$B_{87\ 1/2}$	8-15	2.12	2.08	3.40	7.21	221	30.61	2850	3450	838	1014
	-	2.08	2.13	3.56	7.40	232	31.39	3710	3710	1040	1040
Avr.	-							3383	3583	977	1036
	-	2.06	2.06	3.33	6.86	223	32.5	3220	3220	961	961
$B_{93\ 3/4}$	8-15	2.07	2.06	3.33	6.90	223	32.3	3150	3150	946	946
	-	2.06	2.06	3.33	6.86	219	31.9	2280	2650	685	795
Avr.	-							2883	3006	864	901
	-	2.04	2.04	3.27	6.68	225	33.7	200	200	61.2	61.2§
$B_{96\ 7/8}$	8-16	2.12	2.05	3.30	7.01	227	32.4	230	230	69.7	69.7
	-	2.10	2.10	3.46	7.27	227	31.2	290	290	83.8	83.8
Avr.	-							240	240	71.5	71.5
Average of Averages.											
A_0 - B_0										5738	7998
A_{25} - B_{25}										4420	8151
A_{50} - B_{50}										3585	5413
A_{75} - B_{75}										2183	2300
$A_{87\ 1/2}$ - $B_{87\ 1/2}$										1484	1514
$A_{93\ 3/4}$ - $B_{93\ 3/4}$										803	856
Average of Highest Breaks.											
A_0 - B_0										6650	9065
A_{25} - B_{25}										5550	9157
A_{50} - B_{50}										4465	5845
A_{75} - B_{75}										2400	2535
$A_{87\ 1/2}$ - $B_{87\ 1/2}$										1647	1647
$A_{93\ 3/4}$ - $B_{93\ 3/4}$										931	962
$A_{96\ 7/8}$ - $B_{96\ 7/8}$										56.0	63.0

*4 days late. †2 days late. §Material very soft.

Series II

RESULTS OF COMPRESSION TESTS.

Tested at age of 52 weeks.

(Neat Specimens)

Serial Number	Spec's made 1916 Date	Dimensions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.05	2.00	3.14	6.44	241	37.42	10000	27050	3185	8615
A_{-0}	6-8	2.00	2.00	3.14	6.28	267	42.52	12800	19940	4076	6350
	-	2.00	2.00	3.14	6.28	232	36.94	3800	13000	1210	4140
Avr.	-							8867	19997	2824	6368
	-	2.00	2.00	3.14	6.28	230	36.62	8000	20500	2548	6529
A_{-25}	6-9	2.05	2.05	3.30	6.76	237	35.06	9500	17500	2879	5303
	-	2.00	2.00	3.14	6.28	228	36.30	6380	21250	2032	6768
Avr.	-							7960	19750	2486	6200
	-	2.00	2.00	3.14	6.28	217	34.55	10000	18900	3185	6019
A_{-50}	6-12	2.00	2.00	3.14	6.28	234	37.26	11520	25400	3669	8089
	-	2.00	1.95	3.02	6.04	220	36.42	13700	17100	4536	5662
Avr.	-							11740	20467	3797	6590
	-	2.00	2.00	3.14	6.28	202	32.14	4370	4370	1392	1392
A_{-75}	6-19	2.00	2.00	3.14	6.28	202	32.14	3500	3500	1115	1115
	-	2.00	2.00	3.14	6.28	205	32.64	5950	5950	1895	1895
Avr.	-							4607	4607	1467	1467
	-	2.05	2.00	3.14	6.44	222	34.50	3760	3760	1197	1197
$A_{-87\ 1/2}$	7-12	2.10	2.00	3.14	6.59	213	32.32	1250	1250	398	398
	-	2.00	2.00	3.14	6.28	209	33.28				
Avr.	-							2505	2505	798	798
	-	2.00	2.00	3.14	6.28	220	35.03	1900	2900	605	924
$A_{-93\ 3/4}$	8-7	2.00	2.00	3.14	6.28	230	36.62	3170	3170	1010	1010
	-	2.00	2.00	3.14	6.28	230	36.62	3870	4050	1232	1290
Avr.	-							2980	3373	949	1075
	-	2.00	2.00	3.14	6.28	200	31.85				
$A_{-96\ 7/8}$	8-8	2.00	2.00	3.14	6.28	210	33.44	60	60	19	19
	-	2.00	2.00	3.14	6.28	205	32.64	80	80	25	25
Avr.	-							70	70	22	22
	-	2.00	2.00	3.14	6.28	237	37.74	18250	27880	5812	8879
B_{-0}	8-9	2.00	2.00	3.14	6.28	237	37.74	15580	25310	4962	8060
	-	2.00	2.00	3.14	6.28	238	37.94	13640	22900	4344	7293
Avr.	-							15823	25363	5039	8077
	-	2.00	2.04	3.26	6.52	235	36.04	11900	23000	3650	7055
B_{25}	8-10	2.04	2.06	3.33	6.79	252	37.11	14620	26580	4390	7982
	-	2.00	2.02	3.17	6.34	232	36.59	14440	21760	4555	6864
Avr.	-							13653	23780	4198	7300
	-	2.01	2.05	3.30	6.63	227	34.24	12250	14430	3712	4373
B_{-50}	8-11	2.04	2.02	3.17	6.47	235	36.62	12000	20690	3785	6527
	-	2.00	2.02	3.17	6.34	230	36.28	12100	22570	3817	7120
Avr.	-							12117	19230	3771	6007
	-	2.04	2.07	3.36	6.85	240	35.04	5590	6000	1664	1786
B_{-75}	8-14	2.07	2.06	3.33	6.89	239	34.69	6300	8200	1892	2462
	-	2.04	2.02	3.17	6.47	217	33.54	6390	7410	2016	2338
Avr.	-							6093	7203	1857	2195
	-	2.07	2.04	3.26	6.75	222	32.89	3810	3810	1169	1169
$B_{-87\ 1/2}$	8-15	2.06	2.05	3.30	6.80	222	32.65	2440	3680	739	1115
	-	2.05	2.04	3.26	6.68	220	32.93	3170	4000	972	1227
Avr.	-							3140	3830	960	1170
	-	2.06	2.06	3.33	6.86	227	33.09	3160	3160	949	949
$B_{-93\ 3/4}$	8-15	2.05	2.05	3.30	6.80	226	33.24	1640	2110	497	639
	-	2.06	2.06	3.33	6.89	230	33.38	3270	3270	982	982
Avr.	-							2690	2847	809	857
	-	2.05	2.04	3.26	6.68	227	33.98	200	200	61	61
$B_{-96\ 7/8}$	8-16	2.02	2.00	3.14	6.34	212	33.44	100	150	32	48
	-	2.02	2.02	3.17	6.40	212	33.12	200	200	63	63
	-							167	183	52	57
		Average of Averages.									
A_{-0} - B_{-0}											7222
A_{-25} - B_{25}											6750
A_{-50} - B_{-50}											6298
A_{-75} - B_{-75}											1832
$A_{-87\ 1/2}$ - $B_{-87\ 1/2}$											984
$A_{-93\ 3/4}$ - $B_{-93\ 3/4}$											966
$A_{-96\ 7/8}$ - $B_{-96\ 7/8}$											

Series II

RESULTS OF COMPRESSION TESTS.

Tested at age of 104 weeks.

(Neat Specimens)

Serial Number	Spec's made 1916 Date	Dimensions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height inches	Diam. inches			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.00	2.05	3.30	6.60	246	37.30	11400	45990	3455	13936
A-$_{0}$	6-8	2.02	2.05	3.30	6.66	246	36.95	12600	46900	3818	14212
	-	2.03	1.98	3.08	6.25	229	86.63	25000	46990	8117	15256
Avr.	-									5130	14468
	-	2.02	2.06	3.33	6.73	246	36.55	11110	28780	3336	8642
A-$_{25}$	6-9	2.03	2.07	3.36	6.82	246	36.51	15000	29840	4464	8880
	-	2.05	2.07	3.36	6.89	245	35.60	4000	22300	1190	6637
Avr.	-									2997	8053
	-	2.02	1.98	3.08	6.22	218	35.10	8820	12400	2863	4025
A-$_{50}$	6-12	2.05	2.00	3.14	6.44	223	34.61	6600	7480	2101	2381
	-	2.01	2.03	3.23	6.49	237	36.55	9670	14320	2986	4435
Avr.	-									2650	3614
	-	2.06	2.06	3.33	6.86	217	31.61	4230	4740	1271	1422
A-$_{75}$	6-19	2.05	2.01	3.17	6.50	207	31.80	4990	5100	1573	1609
	-	2.03	1.99	3.11	6.31	202	32.00	3530	3530	1135	1135
Avr.	-									1326	1389
A-$_{87\ 1/2}$	7-12										
Avr.	-										
	-	2.08	2.00	3.14	6.53	220	38.65	2450	2450	781	781
A-$_{93\ 3/4}$	8-7	2.12	2.07	3.36	7.12	220	30.90	2240	2720	667	810
	-	2.13	2.06	3.33	7.09	227	32.00	2220	2350	667	705
Avr.	-									705	765
	-	2.03	1.98	3.08	6.25	204	32.61				No
A-$_{96\ 7/8}$	8-8										
	-										
Avr.	-										No
	-	2.08	2.09	3.41	7.09	248	34.95	13000	27000	3815	7910
B-$_{0}$	8-9	2.08	2.06	3.33	6.93	245	35.35	16240	28840	4872	8662
	-	2.10	2.05	3.30	6.93	247	35.61	15650	29890	4740	9070
Avr.	-									4476	8547
	-	2.20	2.10	3.44	7.57	235	31.05	12840	18540	3680	5390
B-$_{25}$	8-10	2.12	2.01	3.17	6.73	220	32.65	12650	17660	3980	5550
	-										
Avr.	-									3830	5470
	-	2.20	2.08	3.39	7.46	225	30.11	14040	14710	4150	4348
B-$_{50}$	8-11	2.14	2.04	3.26	6.98	220	31.48	8330	17250	2555	5291
	-	2.16	2.06	3.33	7.19	227	31.55	8630	14420	2591	4340
Avr.	-									3099	4660
	-	2.18	2.04	3.26	7.11	230	32.35	6300	7340	1931	2249
B-$_{75}$	8-14	2.14	2.01	3.17	6.78	238	35.08	8070	8070	2543	2543
	-	2.20	2.10	3.44	7.57	250	33.00	8230	8360	2392	2431
Avr.	-									2289	2408
	-	2.10	2.08	3.39	7.12	248	34.90	4180	4180	1234	1234
B-$_{87\ 1/2}$	8-15	2.12	2.08	3.39	7.19	242	33.65	4070	4110	1200	1211
	-	2.16	2.06	3.33	7.19	240	33.40				
Avr.	-									1217	1222
	-	2.20	2.00	3.14	6.91	240	34.70	890	2660	283	848
B-$_{93\ 3/4}$	8-15	2.18	2.04	3.26	7.10	237	33.35	3530	4210	1082	1290
	-	2.14	2.01	3.17	6.78	232	34.20	3370	4040	1062	1273
Avr.	-									809	1137
	-	2.10	2.00	3.14	6.60	225	34.05				No
B-$_{96\ 7/8}$	8-16	2.12	2.05	3.30	6.99	230	32.90	40			No
	-										
	-										No
		Average of Averages.									
A-$_{0}$ - B-$_{0}$											11508
A-$_{25}$ - B-$_{25}$											4893
A-$_{50}$ - B-$_{50}$											4137
A-$_{75}$ - B-$_{75}$											1899
A$_{87\ 1/2}$ - B$_{87\ 1/2}$											
A-$_{93\ 3/4}$ - B-$_{93\ 3/4}$											951
A-$_{96\ 7/8}$ - B-$_{96\ 7/8}$											No

Series II

RESULTS OF COMPRESSION TESTS.

(Mortar Specimens)

Tested at age of 4 weeks

Serial Number	Spec's made 1916 Date	Dimensions				Weight		Load		Stress	
		Height inches	Diam. inches	Area in Sq. in.	Vol. in Cu. in.	Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.04	2.05	3.26	6.65	249	37.41		6360		1954
A-$_0$	6-9	2.06	2.02	3.21	6.61	244	36.90		5210		1623
	-	2.05	2.01	3.18	6.51	248	38.05		6900		2171
Avr.	-								6157		1916
	-	2.06	2.02	3.21	6.61	247	37.31		5660		1765
A_{25}	6-9	2.04	2.00	3.14	6.42	242	37.68		6960		2218
	-	2.06	2.00	3.14	6.48	243	37.48		6210		1980
Avr.	-								6277		1988
	-	2.05	1.98	3.08	6.32	235	37.18		4420		1434
A_{50}	6-12	2.10	2.02	3.21	6.75	252	37.31		4730		1474
	-	2.04	1.98	3.08	6.28	235	37.40		4690		1523
Avr.	-								4613		1477
	-	2.10	2.04	3.27	6.85	253	36.95				†
A_{75}	6-19	2.10	2.00	3.14	6.59	239	36.27		2590		824
	-	2.06	1.98	3.08	6.34	237	37.40	2050	2320	665	753
Avr.	-							2050	2455	665	789
	-	2.14	2.10	3.46	7.42	260	35.00	1170	1170	338	338
$A_{87\ 1/2}$	7-12	2.10	2.02	3.21	6.75	240	35.51		1040		324
	-	2.10	2.00	3.14	6.59	237	35.94	1020	1130	325	360
Avr.	-							1095	1113	332	340
	-										No
$A_{93\ 3/4}$	8-7										No
	-										No
Avr.	-										No
	-										No
$A_{96\ 7/8}$	8-8										No
	-										No
Avr.	-										No
	-	2.16	2.05	3.26	7.04	266	37.79		6250		1918
B-$_0$	8-10	2.10	2.05	3.26	6.85	253	37.90	4420	5120	1355	1571
	-	2.15	2.01	3.18	6.84	252	36.85		5340		1678
Avr.	-							4420	5570	1355	1722
	-	2.15	2.00	3.14	6.75	255	37.75		6560		2090
B_{25}	8-10	2.11	2.00	3.14	6.62	252	38.10		6190		1974
	-	2.14	2.00	3.14	6.72	252	37.50		5880		1875
Avr.	-								6210		1980
	-	2.11	2.01	3.18	6.71	250	37.25		3270		1028
B_{50}	8-11	2.13	2.05	3.26	6.94	263	37.92		2930		898
	-	2.18	2.01	3.18	6.93	250	36.05		2830		889
Avr.	-								3010		938
	-	2.14	2.09	3.44	7.35	258	35.10		1070		311
B_{75}	8-14	2.10	2.04	3.27	6.85	256	37.35		1570		486
	-	2.04	2.00	3.14	6.40	240	37.50		1580		503
Avr.	-								1407		431
	-	2.18	2.06	3.33	7.26	256	35.21		1140		342
$B_{87\ 1/2}$	8-15	2.15	2.00	3.14	6.75	244	36.15		975		311
	-	2.15	2.04	3.27	7.04	248	35.26		890		272
Avr.	-								1002		308
	-	2.10	2.03	3.24	6.80	247	36.30	240	320	74	99
$B_{93\ 3/4}$	8-16	2.10	2.03	3.24	6.80	242	35.58		230		71
	-	2.10	2.03	3.24	6.80	243	35.71		190		59
Avr.	-							240	247	74	76
	-	2.00	2.04	3.27	6.54	240	36.70		1040		318
$B_{96\ 7/8}$	8-16	2.15	2.02	3.21	6.90	224	32.45		880		274
	-	2.12	2.01	3.18	6.74	240	31.00		520		164
Avr.	-								813		252
Average of Averages.											
A_0 - B_0											1819
A_{25} - B_{25}											1984
A_{50} - B_{50}											1208
A_{75} - B_{75}											610
$A_{87\ 1/2}$ - $B_{87\ 1/2}$											324
Average of Highest Breaks.											
A_0 - B_0											2045
A_{25} - B_{25}											2154
A_{50} - B_{50}											1275
A_{75} - B_{75}											663
$A_{87\ 1/2}$ - $B_{87\ 1/2}$											351

†Accidentally broken.

Series II

RESULTS OF COMPRESSION TESTS.

Tested at age of 24 weeks.

(Mortar Specimens)

Serial Number	Date made 1916 Date	Dimensions		Area in Sq. in.	Vol. in Cu. in.	Weight		Load		Stress	
		Height	Diam.			Total Grams	Unit Grams	1st Cr. Pounds	Ult. Pounds	1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.02	2.02	3.20	6.46	251	38.81	8110	8110	2535	2535
A_0	6-9	2.03	1.99	3.11	6.32	240	38.00	7770	7770	2500	2500 *
	-	2.03	1.99	3.11	6.32	240	38.00	8720	8720	2810	2810
Avr.	-							8200	8200	2615	2615
	-	2.03	2.00	3.14	6.37	251	39.40	9430	9430	3000	3000
A_{25}	6-9	2.05	1.98	3.08	6.32	245	38.75	8230	8230	2670	2670 *
	-	2.04	1.98	3.08	6.28	242	38.51	7440	7440	2315	2315
Avr.	-							8366	8366	2661	2661
	-	2.03	1.99	3.11	6.32	238	37.67	6760	6760	2175	2175
A_{50}	6-12	2.06	1.98	3.08	6.35	237	37.30	6720	6720	2180	2180
	-	2.01	1.98	3.08	6.18	237	38.33	6860	6864	2215	2215
Avr.	-							6780	6781	2190	2190
	-	2.08	1.99	3.11	6.47	252	38.95	3660	3660	1170	1170
A_{75}	6-19	2.06	2.03	3.24	6.67	250	37.48	3960	3960	1221	1221
	-	2.05	1.98	3.08	6.32	248	39.20	3610	3610	1171	1171
Avr.	-							3743	3743	1187	1187
	-	2.06	2.02	3.20	6.59	251	38.10	1500	1710	469	534
$A_{87\ 1/2}$	7-12	2.06	1.97	3.05	6.28	239	38.00	1200	1280	393	420 †
	-	2.05	2.00	3.14	6.44	241	37.45	1850	1850	589	589 §
Avr.	-							1515	1613	1449	514
	-	2.10	1.93	2.92	6.13	215	39.9	200	255	68.4	68.7
$A_{93\ 3/4}$	8-7	2.09	1.96	3.01	6.28	245	39.1	100	170	33.3	56.4
	-	2.06	1.98	3.07	6.32	249	39.4	120	260	39.1	84.6
Avr.	-							140	228	46.9	69.9
	-										
$A_{96\ 7/8}$	8-8										
	-										
Avr.	-										
	-	2.10	2.10	3.46	7.26	270	37.2	5000	6600	1445	1910
B_0	8-10	2.10	2.10	3.46	7.26	268	36.9	7060	7060	2020	2020
	-	2.10	2.10	3.46	7.26	271	37.3	8800	8800	2542	2542
Avr.	-							6953	7487	2010	2160
	-	2.09	2.04	3.26	6.81	267	39.3	6700	6700	2050	2050
B_{25}	8-10	2.07	2.05	3.30	6.83	260	38.1	5000	6680	1530	2020
	-	2.05	2.04	3.26	6.68	259	38.8	7450	7450	2285	2285
Avr.	-							6383	6910	1960	2115
	-	2.08	2.00	3.14	6.53	267	40.8	2820	2820	897	897
B_{50}	8-11	2.08	2.00	3.14	6.53	263	40.3	3000	3000	955	955
	-	2.11	2.04	3.27	6.90	274	39.7	3750	5560	1147	1700
Avr.	-							3190	3793	1005	1195
	-	2.08	1.97	3.05	6.34	239	37.7	1000	1020	328	335
B_{75}	8-14	2.02	2.00	3.14	6.35	238	37.5	1510	1510	480	480
	-	2.12	2.01	3.17	6.71	260	38.7	1490	1490	470	470
Avr.	-							1333	1340	428	431
	-	2.10	2.00	3.14	6.60	245	37.2	1200	1200	382	382
$B_{87\ 1/2}$	8-15	2.10	2.01	3.17	6.66	257	38.6	1165	1165	368	368
	-	2.15	1.99	3.11	6.68	236	35.4	960	960	308	308
Avr.	-							1142	745	353	353
	-	2.15	2.00	3.14	6.75	237	35.1	770	770	245	245
$B_{93\ 3/4}$	8-16	2.10	2.00	3.14	6.60	240	36.4	610	610	194	194
	-	2.05	2.01	3.17	6.50	259	39.8	510	510	161	161
Avr.	-							630	630	202	202
	-										
$B_{96\ 7/8}$	8-16										
	-										
	-										
Avr.	-										
		Average of Averages.									
		A_0 - B_0								2312	2387
		A_{25} - B_{25}								2310	2388
		A_{50} - B_{50}								1597	1692
		A_{75} - B_{75}								807	809
		$A_{87\ 1/2}$ - $B_{87\ 1/2}$								901	434
		$A_{93\ 3/4}$ - $B_{93\ 3/4}$								124	136
		Average of Highest Breaks.									
		A_0 - B_0								2676	2676
		A_{25} - B_{25}								2642	2642
		A_{50} - B_{50}								1681	1957
		A_{75} - B_{75}								850	850
		$A_{87\ 1/2}$ - $B_{87\ 1/2}$								485	485
		$A_{93\ 3/4}$ - $B_{93\ 3/4}$								157	165

*Five days late. †Defective. §Two days late.

Series II

RESULTS OF COMPRESSION TESTS.

Tested at age of 52 weeks.

(Mortar Specimens)

Serial Number	Spec's made 1916 Date	Dimensions Height inches	Dimensions Diam. inches	Area in Sq. in.	Vol. in Cu. in.	Weight Total Grams	Weight Unit Grams	Load 1st Cr. Pounds	Load Ult. Pounds	Stress 1st Cr. lb./sq. in.	Stress Ult. lb./sq. in.
	-	2.00	2.00	3.14	6.28	251	39.97	6000	8000	1911	2548
A-$_{0}$	6-9	2.00	2.00	3.14	6.28	251	39.97	6500	6500	2070	2070
	-	2.00	2.00	3.14	6.28	251	39.97	7500	7500	2385	2385
Avr.	-							6667	7333	2122	2334
	-	2.00	2.00	3.14	6.28	232	36.94	6420	6420	2045	2045
A-$_{25}$	6-9	2.00	2.00	3.14	6.28	241	38.41	7750	7750	2468	2468
	-	2.00	2.00	3.14	6.28	245	39.01	8280	8280	2618	2618
Avr.	-							7483	7483	2377	2377
	-	2.00	2.02	3.20	6.40	252	39.38	8000	8000	2500	2500
A-$_{50}$	6-12	2.01	2.04	3.29	6.61	249	37.67	5860	5860	1781	1781
	-	2.02	2.00	3.14	6.34	256	40.37	5200	6690	1656	2131
Avr.	-							6353	6850	1979	2187
	-	2.00	2.00	3.14	6.28	249	37.67	3030	3030	965	965
A-$_{75}$	6-19	2.10	2.00	3.14	6.28	254	40.44	3380	3380	1076	1076
	-	2.00	2.00	3.14	6.28	240	38.25	2420	2420	771	771
Avr.	-							2943	2943	937	937
	-	2.05	2.00	3.14	6.28	245	39.01	1110	1110	354	354
A-$_{87\ 1/2}$	7-12	2.05	2.00	3.14	6.28	244	38.82	1800	1800	573	573
	-	2.00	2.00	3.14	6.28	259	41.40	2000	2000	637	637
Avr.	-							1637	1637	521	521
	-										No
A-$_{93\ 3/4}$	8-7										No
	-										No
Avr.	-										No
	-										No
A-$_{96\ 7/8}$	8-8										No
	-										No
Avr.	-										No
	-	2.00	2.00	3.14	6.28	247	39.33	10000	10280	3185	3274
B-$_{0}$	8-10	2.00	2.00	3.14	6.28	255	40.76	12150	12150	3869	3869
	-	2.00	2.00	3.14	6.28	245	39.01	11960	12450	3809	3965
Avr.	-							11370	11627	3621	3703
	-	2.05	2.08	3.39	6.95	272	39.14	5830	5830	1720	1720
B-$_{25}$	8-10	2.07	2.05	3.30	6.83	270	39.53	7490	7490	2270	2270
	-	2.02	2.05	3.30	6.67	255	38.25	8080	8080	2448	2448
Avr.	-							7133	7133	2146	2146
	-	2.00	2.05	3.30	6.60	251	38.03	960	2410	291	730
B-$_{50}$	8-11	2.02	2.05	3.30	6.67	257	38.53	3800	3800	1152	1152
	-	2.05	2.06	3.33	6.83	262	38.36	2000	2000	601	601
Avr.	-							2253	2737	681	828
	-	2.04	2.00	3.14	6.21	240	38.65	2000	2000	637	637
B-$_{75}$	8-14	2.03	2.00	3.14	6.28	239	38.06	2150	2150	685	685
	-	2.05	2.00	3.14	6.28	241	38.38	1580	1580	503	503
Avr.	-							1910	1910	608	608
	-	2.08	2.05	3.30	6.86	255	37.17	4420	4420	1340	1340
B-$_{87\ 1/2}$	8-15	2.07	2.03	3.23	6.69	247	36.92	2520	3000	780	929
	-	2.05	2.07	3.36	6.89	267	38.75	3480	3480	1036	1036
Avr.	-							3473	3633	1052	1102
	-	2.05	2.00	3.14	6.28	242	38.54	500	500	159	159
B-$_{93\ 3/4}$	8-16	2.04	2.00	3.14	6.28	240	38.22	480	480	153	153
	-	2.05	2.00	3.14	6.28	245	39.01	790	790	252	252
Avr.	-							590	590	188	188
	-	2.06	2.01	3.17	6.53	250	38.28	900	900	284	284
B-$_{96\ 7/8}$	8-16										
	-										
Avr.	-							900	900	284	284
	-										
		Average of Averages.									
A-$_{0}$ - B-$_{0}$											3018
A-$_{25}$ - B-$_{25}$											2262
A-$_{50}$ - B$_{50}$											1482
A-$_{75}$ - B-$_{75}$											772
A-$_{87\ 1/2}$ - B-$_{87\ 1/2}$											812
A-$_{93\ 3/4}$ - B-$_{93\ 3/4}$											
A-$_{96\ 7/8}$ - B-$_{96\ 7/8}$											

Series II

RESULTS OF COMPRESSION TESTS.

Tested at age of 104 weeks.

(Mortar Specimens)

Serial Number	Spec's made 1916 Date	Dimensions Height inches	Diam. inches	Area in Sq. in.	Vol. in Cu. in.	Weight Total Grams	Unit Grams	Load 1st Cr. Pounds	Ult. Pounds	Stress 1st Cr. lb./sq. in.	Ult. lb./sq. in.
	-	2.07	2.10	3.44	7.12	247	34.70	6510	7210	1895	2095
A-$_{0}$	6-9	2.00	1.98	3.08	6.16	244	39.60	5050	6960	1640	2255
	-	2.04	2.05	3.31	6.75	253	37.45	4440	6930	1340	2095
Avr.	-									1625	2148
	-	2.07	2.01	3.17	6.55	245	37.40	8870	9200	2790	2900
A-$_{25}$	6-9	2.02	1.98	3.08	6.23	237	38.05	3000	5200	975	1685
	-										
Avr.	-									1883	2293
	-	2.05	2.03	3.20	6.57	251	38.20	4700	6080	1465	1895
A-$_{50}$	6-12	2.04	2.03	3.20	6.54	244	37.30		2610		815
	-										
Avr.	-										1355
	-	2.10	2.03	3.20	6.72	254	37.75		3000		938
A-$_{75}$	6-19	2.08	2.00	3.14	6.54	239	36.55		2420		768
	-	2.07	2.01	3.17	6.56	243	37.00		3200		1010
Avr.	-										905
	-										
A-$_{87\ 1/2}$	7-12										
	-										
Avr.	-										
	-	2.14	2.01	3.17	6.78	252	37.15				No
A-$_{93\ 3/4}$	8-7	2.15	1.99	3.11	6.69	242	36.15				No
	-	2.16	1.98	3.08	6.67	242	36.25				No
Avr.	-										No
	-										
A-$_{96\ 7/8}$	8-8										
	-										
Avr.	-										
	-	2.20	2.04	3.27	7.20	260	36.10	9650	9650	2950	2950
B-$_{0}$	8-10	2.20	2.00	3.14	6.92	242	34.95	2580	5470	820	1735
	-										
Avr.	-									1885	2343
	-	2.16	2.06	3.33	7.19	240	33.40	3530	7150	1059	2148
B-$_{25}$	8-10	2.20	2.06	3.33	7.33	252	34.38	4150	4380	1248	1318
	-										
B-$_{0}$	8-10	2.20	2.00	3.14	6.92	242	34.95	2580	5470	820	1735
	-										
B-$_{50}$	8-11										
	-										
Avr.	-										
	-	2.14	2.08	3.41	7.30	270	36.95	1190	1730	350	508
B$_{75}$	8-14	2.22	2.06	3.34	7.43	272	36.60	1220	1690	365	507
	-	2.24	2.04	3.27	7.33	275	37.50	1560	2280	478	698
Avr.	-									398	571
	-	2.16	2.08	3.41	7.36	255	34.60	1760	1760	518	518
B-$_{87\ 1/2}$	8-15	2.14	2.00	3.14	6.72	257	38.25	1790	1790	570	570
	-	2.22	2.06	3.34	7.42	265	35.70	1110	1110	332	332
Avr.	-									473	473
	-	2.22	2.00	3.14	6.98	260	37.20	360	610	114	194
B-$_{93\ 3/4}$	8-16	2.20	2.05	3.31	7.28	257	35.30	810	1430	245	433
	-										
Avr.	-									190	314
	-										
B-$_{96\ 7/8}$	8-16										
	-										
Avr.	-										
	-										
		Average of Averages.									
A_0 - B_0											2245
A_{25} - B_{25}											3882
A_{50} - B_{50}											
A_{75} - B_{75}											738
$A_{87\ 1/2}$ - $B_{87\ 1/2}$											
$A_{93\ 3/4}$ - $B_{93\ 3/4}$											
$A_{96\ 7/8}$ - $B_{96\ 7/8}$											

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Vol. 5, No. 4, Never Published.

Vol. 6, No. 1, Never Published.

Vol. 6, No. 2, March, 1914. 43rd Annual Catalogue, 1913-14.

Vol. 6, No. 3, Never Published.

Vol. 6, No. 4, Never Published.

Vol. 7, No. 1, Never Published.

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